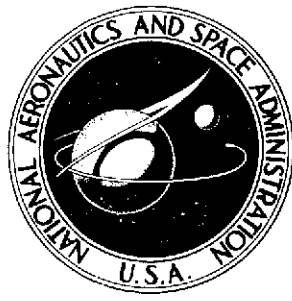


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MEMORANDUM

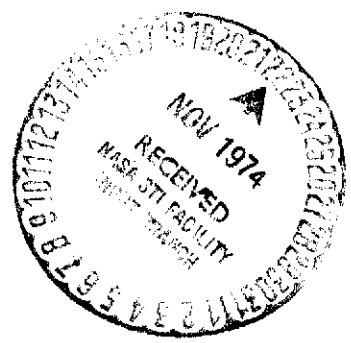


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A COMPUTER PROGRAM FOR PLOTTING
STRESS-STRAIN DATA FROM COMPRESSION,
TENSION, AND TORSION TESTS OF MATERIALS

*by Anne Greenbaum, Donald J. Baker,
and John G. Davis, Jr.*
*Langley Research Center
Hampton, Va. 23665*



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16. Abstract <p>A computer program for plotting stress-strain curves obtained from compression and tension tests on rectangular (flat) specimens and circular-cross-section specimens (rods and tubes) and both stress-strain and torque-twist curves obtained from torsion tests on tubes is presented in detail. The program is written in FORTRAN IV language for the Control Data 6000 series digital computer with the SCOPE 3.0 operating system and requires approximately 110000 octal locations of core storage. The program has the capability of plotting individual strain-gage outputs and/or the average output of several strain gages and the capability of computing the slope of a straight line which provides a least-squares fit to a specified section of the plotted curve. In addition, the program can compute the slope of the stress-strain curve at any point along the curve. The computer program input and output for three sample problems are presented.</p>					
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By Anne Greenbaum and Donald J. Baker
Langley Directorate, U.S. Army Air Mobility R&D Laboratory

John G. Davis, Jr.
Langley Research Center

SUMMARY

A computer program for plotting stress-strain curves obtained from compression and tension tests on rectangular (flat) specimens and circular-cross-section specimens (rods and tubes) and both stress-strain and torque-twist curves obtained from torsion tests on tubes is presented in detail. The program has the capability of plotting individual strain-gage outputs and/or the average output of several strain gages and the capability of computing the slope of a straight line which provides a least-squares fit to a specified section of the plotted curve. In addition, the program can compute the slope of the stress-strain curve at any point along the curve. The program, its subroutines, and their variables are listed and defined. The computer input and output for three sample problems are presented in printed and plotted form to aid the user in setting up and utilizing the program.

The program is written in FORTRAN IV language for the Control Data 6000 series digital computer with the SCOPE 3.0 operating system and requires approximately 110000 octal locations of core storage. A typical problem with seven curves to be plotted, each curve containing approximately 200 data points, requires approximately 50 seconds of central processing time. Output from the program is stored on tape and then used by CalComp or Gerber plotters to construct curves. The input data may be stored on magnetic tape, a data cell, or punched cards.

INTRODUCTION

Reduction of test data to a presentable form, usually hand-drawn plots, can be a time-consuming task. This is especially true if a large number of data points are to be plotted or if the data must be combined in some manner or multiplied by scaling factors prior to plotting. A specific example is construction of the shear-stress—strain curve from strain-gage data obtained from a torsion test on a tubular specimen. Since there

has been a continuing requirement at the Langley Research Center to make such data reductions, a computer program was developed to automate the task of constructing stress-strain plots for compression and tension tests on rectangular (flat) specimens and circular-cross-section specimens (rods and tubes) and stress-strain and torque-twist plots for torsion tests on tubular specimens. The program plots individual strain-gage outputs and/or the average output of several strain gages. The program also has the capability of computing the slope of a straight line which provides a least-squares fit to a specified section of the plotted curve and can compute the slope of the stress-strain curve at any point along the curve. The program is written in FORTRAN IV language for the Control Data 6000 series digital computer with the SCOPE 3.0 operating system. The input data may be stored on magnetic tape, a data cell, or punched cards. The equations have been programed so that either the International System of Units or the U.S. Customary Units may be used. Conversion factors relating the two systems are given in reference 1, and those pertinent to the present paper are presented in appendix A. This paper describes the program and presents sample problems to aid the user in setting up and utilizing the program.

SYMBOLS

ℓ	length, meters (inches)
P	load, newtons (pounds)
R	radius, meters (inches)
T	torque, newton-meters (inch-pounds)
t	thickness, meters (inches)
w	width, meters (inches)
δ	displacement, meters (inches)
ϵ	strain
θ	twist, radians (degrees)
σ	stress, pascals (pounds force per square inch)

τ shear stress, pascals (pounds force per square inch)

Abbreviations:

KSI kilopounds force per square inch

LVDT linear variable differential transformer

MPA megapascals

MICRO IN/IN micro inches per inch (see description of XMULT in appendix C)

MICRO M/M micro meters per meter (see description of XMULT in appendix C)

O.D. outer diameter, meters (inches)

PA pascals (newtons per square meter)

PSI pounds force per square inch

SG strain gage

PROBLEM DESCRIPTION

The task described herein is the development of a computer program to construct plots of stress-strain data from compression and tension tests and to construct plots of stress-strain and torque-twist data from torsion tests. At the beginning of the effort, the following criteria on program capability were selected:

(1) The program must be capable of reading load, strain, and displacement input data, which are arranged sequentially with respect to time and expressed in appropriate engineering units, from magnetic tape, a data cell, or punched cards.

(2) The program must be capable of plotting data in either the International System of Units or U.S. Customary Units. Data recorded in either system of units can only be plotted in the respective units.

(3) The program must be capable of constructing compression or tension stress-strain plots for either rectangular (flat) specimens or circular-cross-section specimens (rods and tubes) and constructing shear-stress—strain and torque-twist plots for thin-walled circular tubes.

(4) For compression or tension tests, the program must be capable of constructing plots of stress as a function of the output of individual strain gages and/or the average output of up to four specified strain gages (or other strain transducers).

(5) For torsion tests, the program must be capable of constructing plots of stress as a function of the output of individual strain gages, as a function of the average absolute output of the $\pm 45^\circ$ strain gages in a strain rosette, or as a function of the average absolute output of all $\pm 45^\circ$ strain gages in up to six strain rosettes. Also, the program must be capable of constructing torque-twist plots by utilizing the output of LVDT's or other transducers which measure displacements associated with the rotations at two locations along the length of a tubular specimen.

(6) The program must be capable of computing the slope of a straight line which provides a least-squares fit to a specified section of each averaged curve (stress-strain or torque-twist) and computing the tangent modulus (slope) at all points along the average stress-strain curve.

(7) The program must be capable of omitting from the calculations and plots any gages which the user specifies, and it must be capable of making more than one type of plot from one input of the same data set.

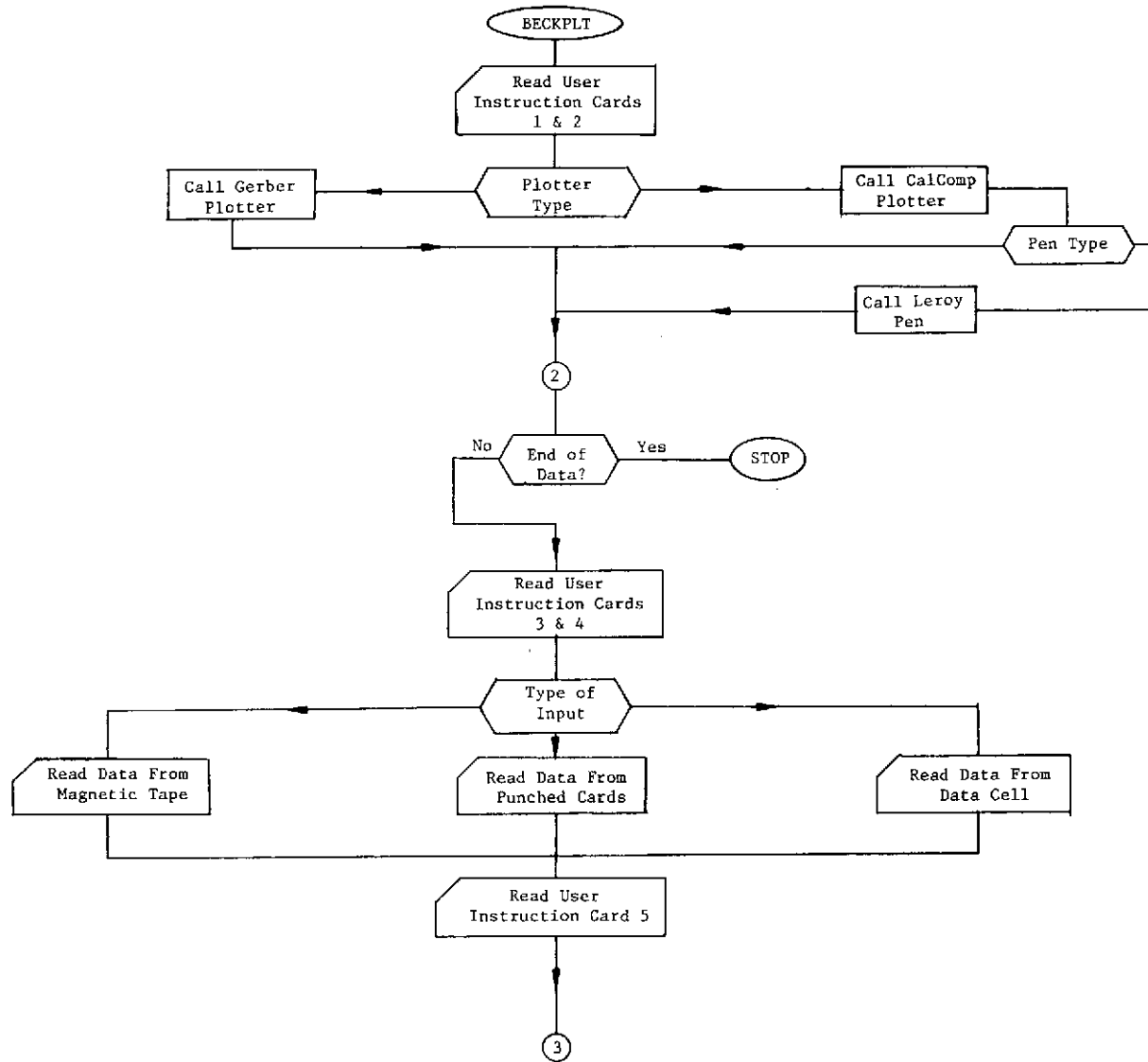
These criteria have been met and table I summarizes the plotting cases that have been programed. Ten cases have been programed and the table indicates specimen and test type, the quantities plotted on each axis, and whether moduli or slope calculations can be made for the case. Figure 1 shows sketches of specimen geometry for compression, tension, and torsion test specimens.

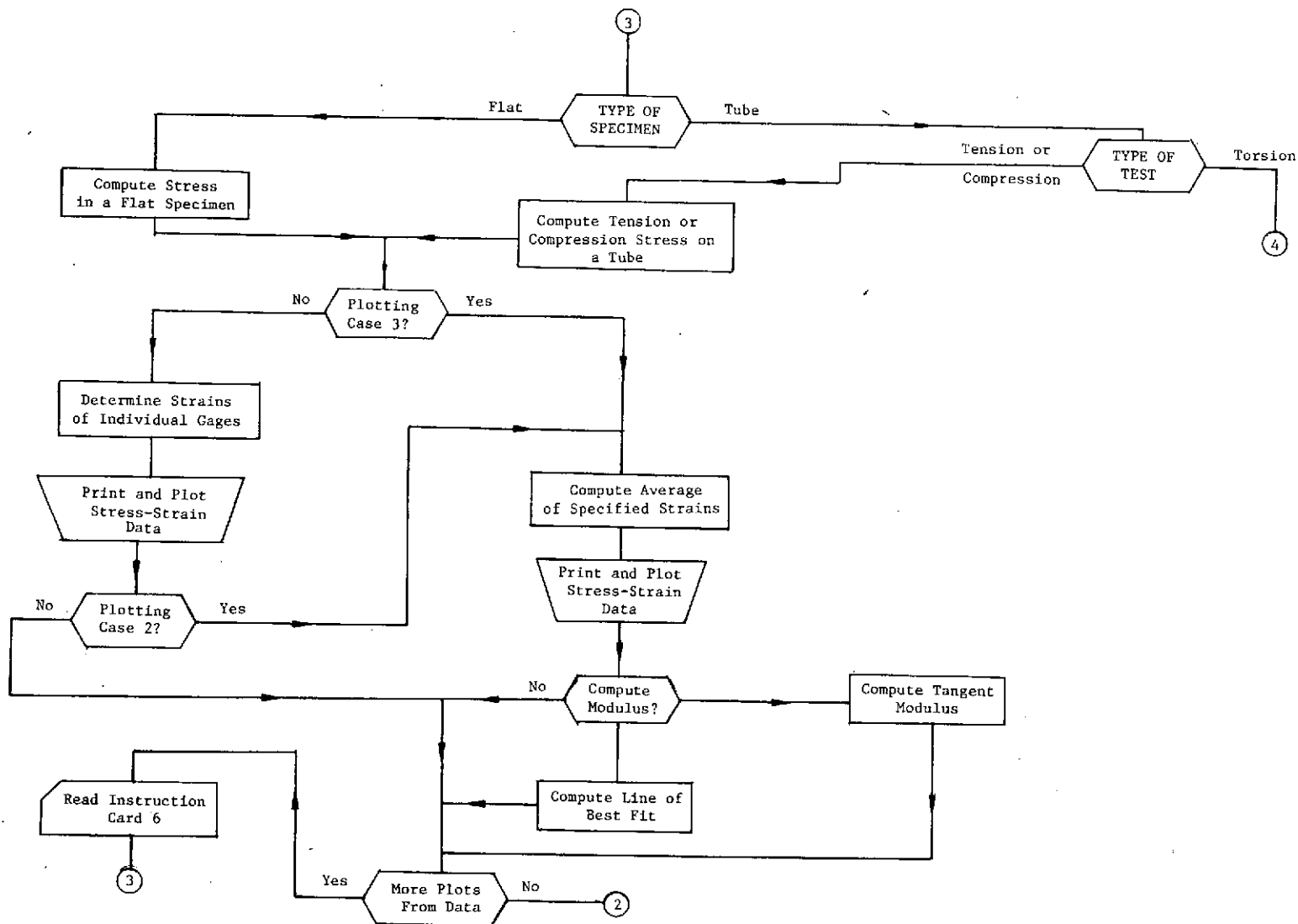
PROGRAM DESCRIPTION

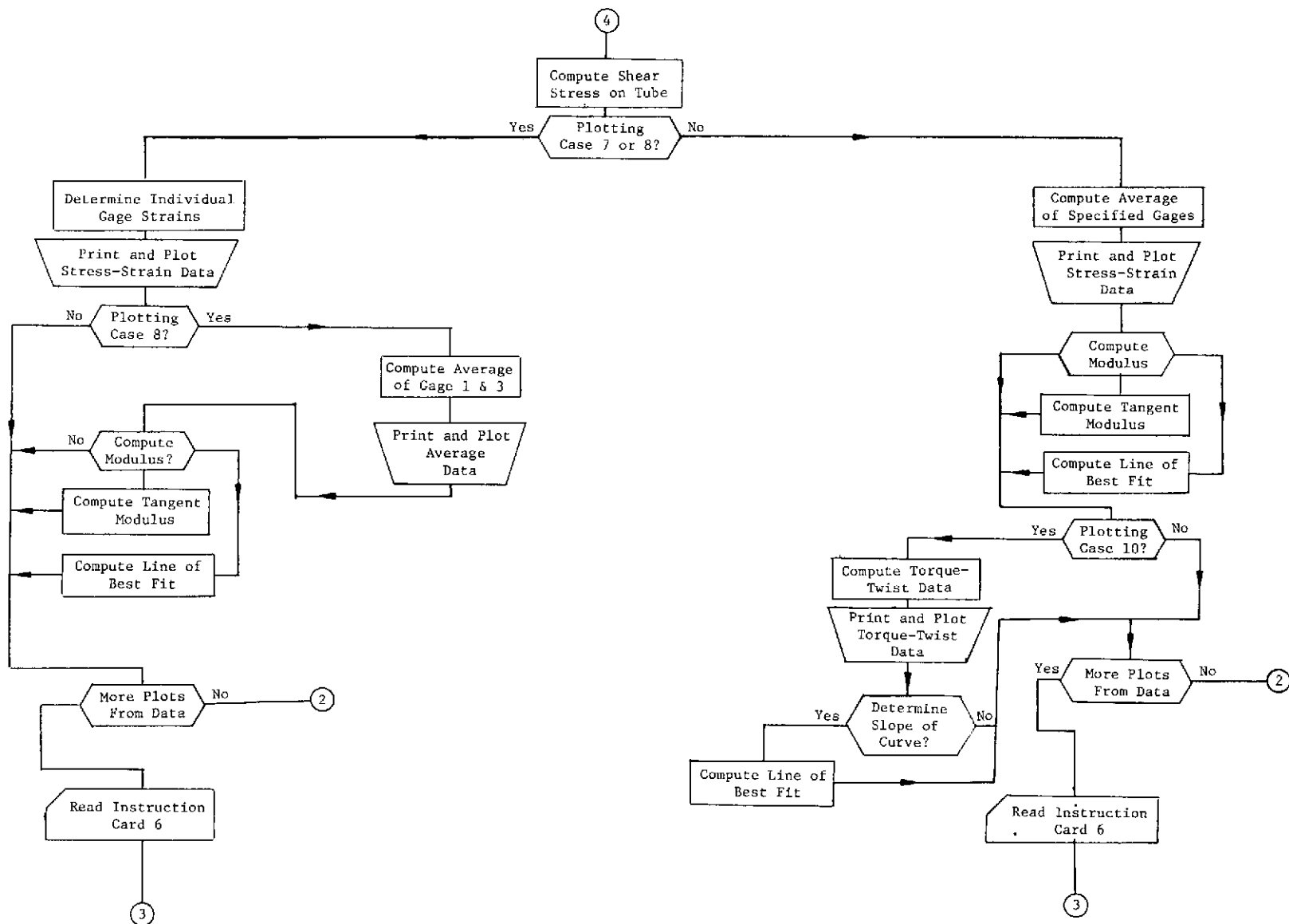
The computer program is written in FORTRAN IV language for the Control Data 6000 series digital computer with the SCOPE 3.0 operating system. With the present dimensions, the program requires approximately 110000 octal locations of core storage. A typical case with seven curves to be plotted, each curve containing approximately 200 data points, requires approximately 50 seconds of central processing time. During job execution, input data read from a data cell or magnetic tape are temporarily stored on a disk file (designated as tape 30 in the program listing). As currently written, the program is limited to a maximum of 20 data channels (18 if stored on a data cell) and 414 data frames per run, with 398 frames per run plotted. Dimension statements can be changed to allow for a larger number of channels and frames. A data channel is a listing that contains all data values derived from one output device (force transducer, strain gage, LVDT, etc.). A data frame is defined as all data values recorded at one value of time.

Thus, one data frame contains a data value for each output device. To use the program as it is currently written, the data must be identified by frame number and stored sequentially by frame number.

The main program, identified herein as BECKPLT, and its subprograms are identified and discussed. Except where noted, all subprograms were written for the task described herein. Appendixes B, C, and D give a source program listing, definitions of the FORTRAN variables, and the Langley Library subroutine MATINV and listing, respectively. A flow chart is shown on pages 6 to 8. The flow chart indicates that, first, instructions that indicate the title of the test, the type of plotter to be used (Gerber or CalComp), how the data are stored (magnetic tape, punched cards, or data cell), the specimen geometry (flat or tube), and test type (tension, compression, or torsion) are read from cards 1 and 2. For simplicity, the type of specimen is given in the program as flat or tube (includes both rods and tubes). The Gerber plot is a smooth continuous curve, whereas the CalComp plot is incremented in small steps. The CalComp plotter requires less time to develop a curve than a Gerber plotter, but the curve is of lower quality. Then the instructions that indicate the particular experiment being analyzed (referred to hereinafter as run), the number of data channels and frames to be plotted, and the curves to be plotted (refer to table I) are read from cards 3 and 4. The data are read from the designated storage device (tape, cards, or data cell) and then the specimen geometry is read from instruction card 5. Next, the load data are converted to stress values by multiplying by the appropriate constants which are a function of test type and specimen geometry. These stress values are stored in the Y-array. One subroutine is next selected to compute and store the strains in the X-array. Selection is based on the type of test and specimen. Possible choices of subroutines are: COMPIND (compression or tension test, individual gage plots), COMPAVG (compression or tension test, average plot), TORIND (torsion test, individual gage plots), and TORAVG (torsion test, average plot). At this point, the coordinates for the stress-strain curve are computed and stored on tape for subsequent use by the selected plotter. Several subroutines can now be requested in the program. Subroutine SLP can be called to calculate the slope of a straight line which provides a least-squares fit to a specified portion of the stress-strain curve. If requested by user instructions to compute the tangent modulus (slope) of the stress-strain curve as a function of stress, subroutine PROPLIM is called. Subroutine PROPLIM computes the coefficients of a second-degree polynomial that provides a least-squares fit to the stress-strain curve. Next, the slope of the stress-strain curve is approximated by the first derivative of the polynomial. The user is cautioned that meaningful tangent-moduli results will be produced only when the second-degree polynomial is a good approximation to the stress-strain curve. Preliminary attempts to compute the tangent moduli by piecewise fitting the data (5 to 15 points) with a second-degree







polynomial generated plots (tangent moduli as a function of stress) of no practical value. Variation of the computed values of tangent moduli ranged up to 15 percent of the mean value, and the curves subsequently plotted had a sawtooth appearance.

More than one plot (case) can be developed from a data set (run) by utilizing instruction card 6. This card indicates the frames to be used and the type of additional plots to be generated. An example of how this feature of the program might be used is the construction of the average shear-stress—strain and torque-twist curves (case 10 in table I) after the program has constructed the individual stress-strain curves (case 7).

With one computer job submittal the stress-strain and/or torque-twist curves for each specimen of a group of specimens can be developed by repeating instruction cards 3 to 6 for each specimen.

The program just described was written primarily to develop data plots for the cases listed in table I. However, this program can be modified so that it can be used to construct data plots for other types of engineering tests. These modifications would include the subprograms that label axes and transform data. The location of the changes can be determined by following the flow chart just discussed.

PROGRAM USAGE

A typical program deck setup, with punched card input, is shown in figure 2. System control cards are utilized to position magnetic-tape or data-cell inputs for use by the source program. User instruction cards, described later in this section, are utilized for control of plots and computation of the slope of the curves. A detailed description of the output is also given in this section. In order to keep user instructions at a minimum, a pattern for identifying the strain gages and rosettes was selected. (Refer to appendix E.)

Input

Data format.—Input data for the program may be recorded on magnetic tape, a data cell, or punched cards by frame. Each frame includes the load and all strain-gage data recorded at a particular time. Frames are identified by integers which increase monotonically with increasing time from the start of the test. Load or torque values must be stored in the first data channel.

If a magnetic tape is used, test data for each frame must be stored on the tape in the following format which is currently used at Langley Research Center:

Word	Description	Type
1	Mode	Integer
2	2	Integer
3	3	Integer
4	Frame	Integer
5	5.0	Float
6	6.0	Float
7	7	Integer
8	8	Integer
9	9	Integer
10	10	Integer
11	11.0	Float
12	12.0	Float
13	13.0	Float
14	14.0	Float
15	15.0	Float
16	Load or torque	Float
17	Data channels	Float
↓	↓	↓
114		

Record length is 114 words. At the end of a run, a record is written with Mode = 8888. At the end of all data on a tape, a record is written with Mode = 9999. There is an EOF after this record. Mode = 2 for all other data frames.

When a data cell is used, input for each data frame must be in the following format:

Line	FORTTRAN variable name	Description	Format
1	ITST, MRN, MD, IFRA	Test, run, mode, frame	3I12, 24X, I12
2	DTA(IFRA,1),DTA(IFRA,2), DTA(IFRA,3),DTA(IFRA,4), DTA(IFRA,5),DTA(IFRA,6)	Load or torque, first five data channels	6E12.4
3	DTA(IFRA,7),DTA(IFRA,8), DTA(IFRA,9),DTA(IFRA,10), DTA(IFRA,11),DTA(IFRA,12)	Next six data channels	6E12.4
4	DTA(IFRA,13),DTA(IFRA,14), DTA(IFRA,15),DTA(IFRA,16), DTA(IFRA,17),DTA(IFRA,18)	Next six data channels	6E12.4

(For a test with more than 18 channels stored on a data cell, the READ statements in subroutine RDCELL must be changed.)

Input data on punched cards must be in the following format for each data frame:

Card	FORTTRAN variable name	Description	Format
1	IFRA, DTA(IFRA,1), DTA(IFRA,2),DTA(IFRA,3), DTA(IFRA,4),DTA(IFRA,5), DTA(IFRA,6),MD	Frame, load or torque, first five data channels, last card	I4, 6E12.4, I4
2	DTA(IFRA,7),DTA(IFRA,8), DTA(IFRA,9),DTA(IFRA,10), DTA(IFRA,11),DTA(IFRA,12), MD	Next six data channels, last card	6E12.4, I4

Repeat card 2 for all channels. For all data cards except the last card, MD = 2. On last card, MD = 8888 (end of data).

User instruction cards. - The following cards are supplied by the program user to control the graphic and printed output. Cards 1 to 3 have the same format for tension, compression, or torsion tests. However, the format for cards 4 to 6 is a function of test type as indicated herein.

User instruction cards 1 to 3 follow:

Card 1 Test title (4A10)

Column

1 to 40 Title of test. Any characters in columns 1 to 40. This title is printed before all other output and is plotted in front of the graphs. (See section entitled "Sample Problems.")

Card 2 Plotting control (9I4)

Column	FORTTRAN variable	Value	
4	IPLT	1	Use Gerber plotter
		0	Use CalComp plotter

Column	FORTTRAN variable	Value	
8	IPEN	1	Use Leroy pen (for CalComp plotter only)
		0	Use ballpoint pen (for CalComp plotter only)
		0	For Gerber
12	INPT	0	Input data on magnetic tape
		1	Input data on punched cards
		2	Input data on data cell
16	ISPEC	0	Flat specimen
		1	Tube specimen
20	ITEST	0	Tension or compression test
		1	Torsion test
21 to 24	IXSIZE		Length of X-axis for each plot (in inches). For tension or compression tests, $IXSIZE = (IOMOVE) \times (\text{number of curves} + 1)$. For torsion tests, $IXSIZE = (IOMOVE) \times (\text{number of curves} + 1) + (\text{number of rosettes})$. The last term accounts for the extra space between plots for different rosettes
25 to 28	IYSIZE		Length of Y-axis in inches. If this field is blank or = 0, length of Y-axis defaults to 9 inches
29 to 32	IOMOVE		Distance between plots. If this field is blank or = 0, defaults to 2 inches
36	IUNITS	0	Input and output data expressed in U.S. Customary Units
		1	Input and output data expressed in SI Units

Card 3 Run title (4A10)

Column

1 to 40 Title of run. Any characters in columns 1 to 40. This title is printed before other output for this run and is plotted in the lower left-hand corner of the graph for this run. (See section entitled "Sample Problems.")

User instruction cards 4 to 6 for tension or compression tests follow:

Card 4 Run information (4I3,4I2,3I3,18I2,14X,I1)

Column	FORTTRAN variable	Value	
2 to 3	JAC		Number of channels (=1 + number of strain channels)
4 to 6	NRL		First frame to be plotted
7 to 9	NRU		Last frame to be plotted
12	INDAVG		Type of plot (see table I)
		0	Case 1 or 4
		1	Case 2 or 5
		2	Case 3 or 6
13 to 20	IGAGES(1) IGAGES(2) IGAGES(3) IGAGES(4)		Channels to be averaged. See sample problem 2 for example of input data
23	MOD	0	Do not calculate slope
		1	Calculate slope
		2	Calculate tangent moduli
24 to 26	NRLSLP		First frame to be used in calculating slope. May be omitted if MOD \neq 1. If MOD = 1 and this field is blank or 0, defaults to first frame plotted

Column	FORTTRAN variable	Value	
27 to 29	NRUSLP		Last frame to be used in calculating slope. May be omitted if MOD \neq 1. If MOD = 1 and this field is blank or 0, defaults to last frame plotted
30 to 65	NOPLT(1)		Strain gages to be omitted from plot
	NOPLT(2)		
	.		
	NOPLT(18)		
66 to 79			
80	MORE	0	No additional plots (cases) requested for this data set (card 6 must be omitted)
		1	Additional plots to be made for this run

If data are on punched cards, place data for this run after card 4.

Card 5 Sectional data (4F12.0)

Column	FORTTRAN variable	Value	
1 to 12	THICK		Thickness of flat specimen, wall thickness of tube or radius of rod (circular cross section)
13 to 24	WIDTH		Width of flat specimen; or outer diameter of tube specimen or rod
25 to 36	SCFAC	+1	Loads are positive
		-1	Loads are negative
			Loads are multiplied by this variable before calculating stresses

Column	FORTTRAN variable	Value
37 to 48	RMAXSN	Maximum strain value to be plotted

If additional plots were requested for this run, place the following card or cards after card 5.

Card 6 New set of run information (3I3,4I2,3I3,18I2,17X,I1)

Column	FORTTRAN variable	Value	
1 to 3	NRL		First frame to be plotted
4 to 6	NRU		Last frame to be plotted
9	INDAVG		Case type (see table I)
		0	Case 1 or 4
		1	Case 2 or 5
		2	Case 3 or 6
10 to 17	IGAGES(1)		Channels to be averaged
	IGAGES(2)		
	IGAGES(3)		
	IGAGES(4)		
20	MOD	0	Do not calculate slope
		1	Calculate slope
		2	Calculate tangent moduli
21 to 23	NRLSLP		First frame to be used in calculating slope. May be omitted if MOD \neq 1. If MOD = 1 and this field is blank or 0, defaults to first frame plotted
24 to 26	NRUSLP		Last frame to be used in calculating slope. May be omitted if MOD \neq 1. If MOD = 1 and this field is blank or 0, defaults to last frame plotted

Column	FORTTRAN variable	Value	
27 to 62	NOPLT(1)		Strain gages to be omitted from plot
	NOPLT(2)		
	.		
	NOPLT(18)		
63 to 79			
80	MORE	0	No additional plots (cases) requested for this data set (card 6 must be omitted)
		1	Additional plots requested for this run

User instruction cards 4 to 6 for a torsion test follow:

Card 4 Run information (8I3,18I2,19X,I1)

Column	FORTTRAN variable	Value	
2 to 3	JAC		Number of channels (= 1 + number of strain channels + number of deflection (δ) channels (see fig. 1))
4 to 6	NRL		First frame to be plotted
7 to 9	NRU		Last frame to be plotted
12	NROS		Number of rosettes
15	INDAVG		Case type (see table I)
		0	Case 7
		1	Case 9
		2	Case 10
		3	Case 8
18	MOD	0	Do not calculate slope
		1	Calculate slope
		2	Calculate tangent moduli

Column	FORTTRAN variable	Value	
19 to 21	NRLSLP		First frame to be used in calculating slope. May be omitted if MOD \neq 1. If MOD = 1 and this field is blank or 0, defaults to first frame plotted
22 to 24	NRUSLP		Last frame to be used in calculating slope. May be omitted if MOD \neq 1. If MOD = 1 and this field is blank or 0, defaults to last frame plotted
25 to 60	NOPLT(1) NOPLT(2) : : : NOPLT(18)		Strain gages to be omitted from plotting and averaging
61 to 79			
80	MORE	0	No additional plots (cases) requested for this data set (omit card 6)
		1	Additional plots requested for this run

If input data are on punched cards, place data for this run after card 4.

Card 5 Sectional data (6F12.4)

Column	FORTTRAN variable	Value	
1 to 12	THICK		Thickness of tube
13 to 24	WIDTH		Outer diameter of tube
25 to 36	RLENGTH		Distance between arm stations (see fig. 1)
37 to 48	ALENGTH		Length of R (see fig. 1)

Column	FORTTRAN variable	Value	
49 to 60	SCFAC	+1	Loads are positive
		-1	Loads are negative
			Loads are multiplied by this variable before calculating stresses
61 to 72	RMAXSN		Maximum strain value to be plotted

If additional plots were indicated for this run, place the following card or cards after card 5.

Card 6 New set of run information (7I3,18I2,22X,I1)

Column	FORTTRAN variable	Value	
1 to 3	NRL		First frame to be plotted
4 to 6	NRU		Last frame to be plotted
9	NROS		Number of rosettes
12	INDAVG		Case type (see table I)
		0	Case 7
		1	Case 9
		2	Case 10
		3	Case 8
15	MOD	0	Do not calculate slope
		1	Calculate slope
		2	Calculate tangent moduli
16 to 18	NRLSLP		First frame to be used in calculating slope. May be omitted if MOD \neq 1. If MOD = 1 and this field is blank or 0, defaults to first frame plotted

Column	FORTTRAN variable	Value	
19 to 21	NRUSLP		Last frame to be used in calculating slope. May be omitted if MOD \neq 1. If MOD = 1 and this field is blank or 0, defaults to last frame plotted.
22 to 57	NOPLT(1)		Strain gages to be omitted from plot
	NOPLT(2)		
	.		
	.		
	NOPLT(18)		
58 to 79			
80	MORE	0	No additional plots (cases) requested for this data set
		1	Additional plots requested for this run

Repeat card 6 for each plot after the first plot to be made for this run (until MORE = 0). Repeat cards 3 to 6 for each data set in a computer run.

Output

Printed. - Examples of printed and plotted output are presented in the discussion of sample problems. The test title supplied by the user is printed first, followed by the test and specimen type and the plotter. Next, the first run title supplied by the user is printed, followed by a list of data from the first three channels of every fifth or tenth frame (every tenth frame if the total number of frames is greater than 300). This data list is followed by the specimen thickness and width (for flat specimen) or outer diameter (for tube specimen). Next the coordinates of each stress-strain or torque-twist curve to be plotted are printed. These points are printed in pairs with the Y-value (stress or torque) first and the X-value (strain or twist) second. If tangent moduli are computed, they are listed next along with their associated stress-strain points. At the end of the printed output, the number of graphs plotted and the size of the axes are listed.

Plotted. - The test title is printed vertically on the plotting paper before the first plot is constructed. (See fig. 3.) The run title is printed in the lower left-hand corner of the graph, below the X-axis. In graphs with more than one plot, the X-axis is labeled

with a drafting dimension: $\rightarrow|\text{scale factor}|\leftarrow$. In graphs with only one plot, both the X- and Y-axes are numbered at each tick mark. A grid of + 's is also drawn on the graph.

Above the graph, the gage number and the frames used for each plot are written. For plots where the gages to be averaged are specified by the user, the program prints AVG OF and lists these gages. For plots where the gages to be averaged are fixed (cases 9 and 10 in table I), it prints AVG PLOT.

If the tangent moduli have been calculated, they will be plotted as a function of stress on a 9- by 9-in. graph. On the X-axis will be STRESS in PSI or PA and on the Y-axis will be TANGENT MODULI in PSI or PA.

Diagnostics

This program contains a series of error diagnostics as follows:

Fatal errors -

(1) INVALID TEST NUMBER, ITEST = (test number specified). Neither tension, compression, or torsion test is indicated. (ITEST is not 0 or 1.)

(2) INVALID SPECIMEN NUMBER, ISPEC = (specimen number specified). Neither flat nor tube specimen is indicated. (ISPEC is not 0 or 1.)

(3) CANNOT HANDLE TORSION TEST ON FLAT SPECIMEN

(4) TOO MANY CHANNELS, JAC = (number of channels specified). The number of channels specified is greater than 20.

Nonfatal errors -

(1) LAST FRAME TO BE PLOTTED LESS THAN FIRST FRAME

FIRST FRAME = (first frame) LAST FRAME = (last frame)

WILL GO TO NEXT PLOT

This can be used to suppress plotting for a particular run, if desired.

(2) FIRST FRAME FOR SLOPE GREATER THAN LAST FRAME FOR SLOPE.

FIRST FRAME = (first frame for slope) LAST FRAME = (last frame for slope)

WILL NOT FIND SLOPE.

The program will print and plot the points for this run but will not calculate the slope of the line of best fit to any section of the curve.

(3) FIRST FRAME FOR SLOPE INVALID.

FIRST FRAME = (first frame specified for slope)

WILL USE FIRST FRAME PLOTTED.

LAST FRAME = (last frame specified for slope)
WILL USE LAST FRAME PLOTTED.

Problem 1

[illegible]

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The output listing for problem 1 follows:

PROBLEM 1 COMPRESSION TEST

COMPRESSION OR TENSION TEST IN TUBE SPECIMEN
USING CALCOMP PLOTTER WITH LEROY PEN

TUBE NUMBER 2

FRAME	LOAD	SG-1	SG-2
5	6.1760E+02	1.5341E-05	3.8352E-05
10	2.3267E+03	4.1697E-05	1.1005E-04
15	4.1983E+03	6.8367E-05	1.9093E-04
20	6.0229E+03	9.1712E-05	2.6597E-04
25	8.1100E+03	1.2006E-04	3.5351E-04

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155	1.5615E+04	2.2178E-04	6.7200E-04
160	1.7483E+04	2.4679E-04	7.5204E-04
165	1.9301E+04	2.7013E-04	8.3041E-04
170	2.1099E+04	2.9265E-04	9.0545E-04
175	2.2334E+04	3.0932E-04	9.5381E-04

THICKNESS = 1.3081E-03 OUTER DIAMETER = 7.6600E-02

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

STRESS-STRAIN POINTS FOR SG- 1 FRAMES 64 THROUGH 119

FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M
64	7.3814E+00	4.4149E+01	65	7.5646E+00	4.6890E+01	66	8.3380E+00	5.0859E+01	67	1.0018E+01	5.5027E+01
68	1.1173E+01	5.3362E+01	69	1.2428E+01	6.6700E+01	70	1.3784E+01	7.3370E+01	71	1.5064E+01	7.9206E+01
72	1.6231E+01	8.3375E+01	73	1.7287E+01	8.6710E+01	74	1.8703E+01	9.3879E+01	75	1.9383E+01	9.6715E+01
76	2.0725E+01	1.0722E+02	77	2.2220E+01	1.0837E+02	78	2.3688E+01	1.1339E+02	79	2.4881E+01	1.2006E+02
80	2.5961E+01	1.3173E+02	81	2.7041E+01	1.2673E+02	82	2.8383E+01	1.3006E+02	83	2.9149E+01	1.3590E+02
84	3.0215E+01	1.4557E+02	85	3.1359E+01	1.4590E+02	86	3.2513E+01	1.5007E+02	87	3.3794E+01	1.5538E+02
88	3.5087E+01	1.5841E+02	89	3.6354E+01	1.6425E+02	90	3.7598E+01	1.6925E+02	91	3.8840E+01	1.7342E+02
92	4.0046E+01	1.7500E+02	93	4.1301E+01	1.8342E+02	94	4.2536E+01	1.8843E+02	95	4.3749E+01	1.9176E+02
96	4.4941E+01	1.9843E+02	97	4.6147E+01	2.0343E+02	98	4.7349E+01	2.0844E+02	99	4.8582E+01	2.1344E+02
100	4.9774E+01	2.1928E+02	101	5.0904E+01	2.2423E+02	102	5.2034E+01	2.2845E+02	103	5.3177E+01	2.3428E+02
104	5.4294E+01	2.3522E+02	105	5.5392E+01	2.4179E+02	106	5.6641E+01	2.4595E+02	107	5.7984E+01	2.5366E+02
108	5.9252E+01	2.5763E+02	109	6.0570E+01	2.6245E+02	110	6.1864E+01	2.6847E+02	111	6.3169E+01	2.7597E+02
112	6.4424E+01	2.7764E+02	113	6.5713E+01	2.8181E+02	114	6.6973E+01	2.8848E+02	115	6.8228E+01	2.9348E+02
116	6.9495E+01	2.9691E+02	117	7.0501E+01	3.0039E+02	118	7.1555E+01	3.0432E+02	119	7.2145E+01	3.0932E+02

STRESS-STRAIN POINTS FOR SG- 2 FRAMES 64 THROUGH 119

FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M
64	7.3314E+00	1.0500E+02	65	7.5646E+00	1.1005E+02	66	8.3380E+00	1.2673E+02	67	1.0018E+01	1.4257E+02
68	1.1173E+01	1.4752E+02	69	1.2428E+01	1.7592E+02	70	1.3784E+01	1.9426E+02	71	1.5064E+01	2.1010E+02

STRESS-STRAIN POINTS FOR SG- 4 FRAMES 64 THROUGH 119

FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M
64	7.3814E+00	1.6677E+01	65	7.5646E+00	1.8342E+01	66	8.3380E+00	2.1577E+01	67	1.0018E+01	2.6680E+01
68	1.1173E+01	2.2350E+01	69	1.2428E+01	3.4056E+01	70	1.3784E+01	4.5022E+01	71	1.5064E+01	5.0025E+01
72	1.6231E+01	5.6194E+01	73	1.7287E+01	5.9196E+01	74	1.8703E+01	6.4199E+01	75	1.9383E+01	6.8367E+01
76	2.0725E+01	7.5037E+01	77	2.2220E+01	8.0040E+01	78	2.3688E+01	8.6710E+01	79	2.4881E+01	9.2546E+01
80	2.5961E+01	9.6715E+01	81	2.7041E+01	1.0172E+02	82	2.8383E+01	1.0755E+02	83	2.9149E+01	1.1172E+02
84	3.0215E+01	1.1589E+02	85	3.1359E+01	1.2173E+02	86	3.2513E+01	1.2590E+02	87	3.3794E+01	1.3006E+02
88	3.5087E+01	1.2924E+02	89	3.6354E+01	1.4343E+02	90	3.7598E+01	1.4841E+02	91	3.8840E+01	1.5591E+02
92	4.0046E+01	1.6030E+02	93	4.1301E+01	1.6675E+02	94	4.2536E+01	1.7259E+02	95	4.3749E+01	1.7675E+02
96	4.4941E+01	1.8254E+02	97	4.6147E+01	1.8943E+02	98	4.7349E+01	1.9593E+02	99	4.8582E+01	2.0093E+02
100	4.9774E+01	2.0577E+02	101	5.0904E+01	2.1011E+02	102	5.2034E+01	2.1761E+02	103	5.3177E+01	2.2344E+02
104	5.4294E+01	2.2928E+02	105	5.5392E+01	2.3428E+02	106	5.6641E+01	2.3845E+02	107	5.7984E+01	2.4679E+02
108	5.9252E+01	2.5623E+02	109	6.0571E+01	2.5937E+02	110	6.1864E+01	2.6430E+02	111	6.3169E+01	2.7264E+02
112	6.4424E+01	2.7630E+02	113	6.5713E+01	2.8514E+02	114	6.6973E+01	2.9014E+02	115	6.8228E+01	2.9515E+02
116	6.9495E+01	2.9694E+02	117	7.0501E+01	3.0597E+02	118	7.1555E+01	3.1015E+02	119	7.2145E+01	3.1432E+02

STRESS-STRAIN POINTS FOR AVG OF PAGES 2 5 8-0 FRAMES 64 THROUGH 119

FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M	FRAME	STRESS MPA	STRAIN MICRO M/M
64	7.3814E+00	2.8157E+01	65	7.5646E+00	1.0116E+02	66	8.3380E+00	1.1857E+02	67	1.0018E+01	1.3534E+02
68	1.1173E+01	1.5563E+02	69	1.2428E+01	1.6925E+02	70	1.3784E+01	1.8759E+02	71	1.5064E+01	2.0399E+02
72	1.6231E+01	2.1903E+02	73	1.7287E+01	2.3373E+02	74	1.8703E+01	2.4790E+02	75	1.9383E+01	2.6096E+02
76	2.0725E+01	2.3670E+02	77	2.2220E+01	2.4959E+02	78	2.3688E+01	2.6055E+02	79	2.4881E+01	2.7461E+02
80	2.5961E+01	2.4926E+02	81	2.7041E+01	2.6291E+02	82	2.8383E+01	2.7696E+02	83	2.9149E+01	2.9103E+02
84	3.0215E+01	2.8657E+02	85	3.1359E+01	2.8243E+02	86	3.2513E+01	2.9377E+02	87	3.3794E+01	3.0749E+02
88	3.5087E+01	3.2335E+02	89	3.6354E+01	3.4025E+02	90	3.7598E+01	3.5064E+02	91	3.8840E+01	3.5238E+02
92	4.0046E+01	3.4927E+02	93	4.1301E+01	3.5757E+02	94	4.2536E+01	3.7362E+02	95	4.3749E+01	3.9030E+02
96	4.4941E+01	3.7697E+02	97	4.6147E+01	3.7355E+02	98	4.7349E+01	3.8430E+02	99	4.8582E+01	3.9582E+02
100	4.9774E+01	4.7357E+02	101	5.0904E+01	4.8451E+02	102	5.2034E+01	4.9480E+02	103	5.3177E+01	5.0920E+02
104	5.4294E+01	5.2176E+02	105	5.5392E+01	5.5399E+02	106	5.6641E+01	5.6900E+02	107	5.7984E+01	5.8817E+02
108	5.9252E+01	6.0624E+02	109	6.0571E+01	6.2446E+02	110	6.1864E+01	6.4098E+02	111	6.3169E+01	6.5959E+02
112	6.4424E+01	6.7794E+02	113	6.5713E+01	6.9517E+02	114	6.6973E+01	7.1268E+02	115	6.8228E+01	7.2991E+02
116	6.9495E+01	7.4593E+02	117	7.0501E+01	7.5937E+02	118	7.1555E+01	7.7578E+02	119	7.2145E+01	7.9131E+02

NUMBER OF POINTS = 1
 LENGTH OF X AXIS = 20 INCHES
 LENGTH OF Y AXIS = 14 INCHES

REPRODUCIBILITY OF THE
 ORIGINAL PAGE IS POOR

Problem 2

This example illustrates the input and output data from a compression test on a graphite-epoxy tube. The data are expressed in U.S. Customary Units. This problem illustrates the option where more than one type of plot is obtained from a data set (run). First, the output of nine strain gages and the average of the output of gages 2, 5, and 8 are plotted in figure 4. The tangent modulus for the averaged curve (gages 2, 5, and 8) is plotted in figure 5 as a function of applied stress. The dashed curve in figure 5 is hand drawn and represents the slope of the straight line which provides the least-squares fit to the data. Figures 4 and 5 correspond to case 5 in table I. The additional output requested for this computer run is a separate plot of the average output of gages 2, 5, and 8 in figure 6. The slope of the stress-strain curve shown in figure 6 is 10.6×10^6 , as indicated in the printout and by the dashed line in figure 5. A listing of the input data follows:

[illegible]

This data set was obtained from a test on a graphite-epoxy tube.

The output listing for problem 2 follows:

PROBLEM 2 COMPRESSION TEST

COMPRESSION OR TENSION TEST ON TUBE SPECIMEN
USING GERBER PLOTTER

TUBE NUMBER 2

FRAME	LOAD	SG-1	SG-2
5	1.3885E+02	1.5841E-05	3.8352E-05
10	5.2308E+02	4.1687E-05	1.1005E-04
15	9.4398E+02	6.8367E-05	1.9093E-04
20	1.3579E+03	9.1712E-05	2.6597E-04

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75	1.3483E+03	9.6715E-05	2.6513E-04
80	1.8059E+03	1.2173E-04	3.4851E-04
85	2.1814E+03	1.4591E-04	4.2021E-04
90	2.6154E+03	1.6925E-04	4.9942E-04
95	3.0433E+03	1.9176E-04	5.8029E-04
100	3.4624E+03	2.1928E-04	6.6033E-04
105	3.8537E+03	2.4179E-04	7.3453E-04
110	4.3034E+03	2.6847E-04	8.2041E-04
115	4.7461E+03	2.9348E-04	9.0378E-04

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150	3.0695E+03	1.9676E-04	5.8863E-04
155	3.5105E+03	2.2178E-04	6.7200E-04
160	3.9305E+03	2.4679E-04	7.5204E-04
165	4.3392E+03	2.7013E-04	8.3041E-04
170	4.7435E+03	2.9265E-04	9.0545E-04
175	5.0212E+03	3.0932E-04	9.5381E-04

THICKNESS = 5.1500E-02 OUTER DIAMETER = 3.0150E+00

STRESS-STRAIN POINTS FOR SG- 1 FRAMES 64 THROUGH 119

FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN
64	1.0709E+00	4.4189E+01	65	1.0946E+00	4.6690E+01	66	1.2967E+00	5.0859E+01	67	1.4534E+00	5.5027E+01
68	1.6209E+00	5.8362E+01	69	1.8031E+00	6.6700E+01	70	1.9998E+00	7.3370E+01	71	2.1855E+00	7.9206E+01
72	2.3549E+00	8.3375E+01	73	2.5080E+00	8.6710E+01	74	2.6554E+00	9.0879E+01	75	2.8121E+00	9.6715E+01
76	3.0069E+00	1.0338E+02	77	3.2238E+00	1.0839E+02	78	3.4367E+00	1.1339E+02	79	3.6098E+00	1.2006E+02
80	3.7664E+00	1.2173E+02	81	3.9231E+00	1.2673E+02	82	4.0743E+00	1.3006E+02	83	4.2290E+00	1.3590E+02
84	4.3838E+00	1.4257E+02	85	4.5496E+00	1.4591E+02	86	4.7171E+00	1.5007E+02	87	4.9029E+00	1.5508E+02
88	5.0904E+00	1.5841E+02	89	5.2744E+00	1.6425E+02	90	5.4548E+00	1.6925E+02	91	5.6350E+00	1.7342E+02
92	5.8100E+00	1.7509E+02	93	5.9920E+00	1.8342E+02	94	6.1668E+00	1.8843E+02	95	6.3472E+00	1.9176E+02
96	6.5201E+00	1.9443E+02	97	6.6951E+00	2.0343E+02	98	6.8753E+00	2.0844E+02	99	7.0484E+00	2.1344E+02
100	7.2213E+00	2.1928E+02	101	7.3852E+00	2.2428E+02	102	7.5492E+00	2.2845E+02	103	7.7150E+00	2.3242E+02
104	7.8770E+00	2.3762E+02	105	8.0374E+00	2.4179E+02	106	8.2176E+00	2.4596E+02	107	8.4124E+00	2.5346E+02
108	8.5964E+00	2.5763E+02	109	8.7876E+00	2.6346E+02	110	8.9753E+00	2.6847E+02	111	9.1647E+00	2.7597E+02
112	9.3468E+00	2.7764E+02	113	9.5345E+00	2.8181E+02	114	9.7166E+00	2.8848E+02	115	9.8986E+00	2.9348E+02
116	1.0083E+01	2.9681E+02	117	1.0228E+01	3.0098E+02	118	1.0381E+01	3.0432E+02	119	1.0467E+01	3.0932E+02

STRESS-STRAIN POINTS FOR SG- 9 FRAMES 64 THROUGH 119

FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN
64	1.0709E+00	1.6675E+01	65	1.0946E+00	1.8342E+01	66	1.2967E+00	2.1677E+01	67	1.4534E+00	2.6680E+01
68	1.6209E+00	3.3350E+01	69	1.8031E+00	3.9186E+01	70	1.9998E+00	4.5022E+01	71	2.1855E+00	5.0025E+01
72	2.3549E+00	5.4194E+01	73	2.5080E+00	5.9196E+01	74	2.6554E+00	6.4199E+01	75	2.8121E+00	6.8367E+01
76	3.0069E+00	7.5037E+01	77	3.2238E+00	8.0040E+01	78	3.4367E+00	8.6710E+01	79	3.6098E+00	9.2546E+01
80	3.7664E+00	9.0715E+01	81	3.9231E+00	1.0172E+02	82	4.0743E+00	1.0755E+02	83	4.2290E+00	1.1172E+02
84	4.3838E+00	1.1589E+02	85	4.5496E+00	1.2173E+02	86	4.7171E+00	1.2590E+02	87	4.9029E+00	1.3006E+02
88	5.0904E+00	1.3924E+02	89	5.2744E+00	1.4340E+02	90	5.4548E+00	1.4841E+02	91	5.6350E+00	1.5591E+02
92	5.8100E+00	1.6008E+02	93	5.9920E+00	1.6675E+02	94	6.1668E+00	1.7259E+02	95	6.3472E+00	1.7675E+02
96	6.5201E+00	1.8259E+02	97	6.6951E+00	1.8843E+02	98	6.8753E+00	1.9593E+02	99	7.0484E+00	2.0093E+02

STRESS-STRAIN POINTS FOR AVG OF GAGES 2 5 8 -0 FRAMES 64 THROUGH 119

FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN
64	1.0709E+00	9.6159E+01	65	1.0946E+00	1.0116E+02	66	1.2967E+00	1.1867E+02	67	1.4534E+00	1.3534E+02
68	1.6209E+00	1.5063E+02	69	1.8031E+00	1.6925E+02	70	1.9998E+00	1.8759E+02	71	2.1855E+00	2.0399E+02
72	2.3549E+00	2.1900E+02	73	2.5080E+00	2.3373E+02	74	2.6554E+00	2.4790E+02	75	2.8121E+00	2.6096E+02
76	3.0069E+00	2.8070E+02	77	3.2238E+00	2.9959E+02	78	3.4367E+00	3.1905E+02	79	3.6098E+00	3.3461E+02
80	3.7664E+00	3.4906E+02	81	3.9231E+00	3.6246E+02	82	4.0743E+00	3.7769E+02	83	4.2290E+00	3.9103E+02
84	4.3838E+00	4.0687E+02	85	4.5496E+00	4.2243E+02	86	4.7171E+00	4.3827E+02	87	4.9029E+00	4.5550E+02
88	5.0904E+00	4.7301E+02	89	5.2744E+00	4.9025E+02	90	5.4548E+00	5.0664E+02	91	5.6350E+00	5.2387E+02
92	5.8100E+00	5.4027E+02	93	5.9920E+00	5.5750E+02	94	6.1668E+00	5.7362E+02	95	6.3472E+00	5.9030E+02
96	6.5201E+00	6.0697E+02	97	6.6951E+00	6.2365E+02	98	6.8753E+00	6.4060E+02	99	7.0484E+00	6.5644E+02
100	7.2213E+00	6.7367E+02	101	7.3852E+00	6.8951E+02	102	7.5492E+00	7.0480E+02	103	7.7150E+00	7.2092E+02
104	7.8770E+00	7.3676E+02	105	8.0374E+00	7.5176E+02	106	8.2176E+00	7.6900E+02	107	8.4124E+00	7.8817E+02
108	8.5964E+00	8.0624E+02	109	8.7876E+00	8.2346E+02	110	8.9753E+00	8.4098E+02	111	9.1647E+00	8.5959E+02
112	9.3468E+00	8.7794E+02	113	9.5345E+00	8.9171E+02	114	9.7166E+00	9.1268E+02	115	9.8986E+00	9.2991E+02
116	1.0083E+01	9.4686E+02	117	1.0228E+01	9.5937E+02	118	1.0381E+01	9.7578E+02	119	1.0467E+01	9.8131E+02

STRESS	STRAIN	TANGENT MODULUS
1.0709E+03	9.6159E-05	1.0870E+07
1.0946E+03	1.0116E-04	1.0867E+07
1.2967E+03	1.1867E-04	1.0858E+07
1.4534E+03	1.3534E-04	1.0848E+07
1.6209E+03	1.5063E-04	1.0840E+07
1.8031E+03	1.6925E-04	1.0830E+07
1.9998E+03	1.8759E-04	1.0820E+07
2.1855E+03	2.0399E-04	1.0811E+07
2.3549E+03	2.1900E-04	1.0803E+07

9.7166E+03	9.1268E-04	1.0427E+07
9.8986E+03	9.2991E-04	1.0418E+07
1.0083E+04	9.4686E-04	1.0409E+07
1.0228E+04	9.5937E-04	1.0402E+07
1.0381E+04	9.7578E-04	1.0393E+07
1.0467E+04	9.8131E-04	1.0390E+07

STRESS-STRAIN POINTS FOR AVG OF GAGES 2 5 8 -U FRAMES 64 THROUGH 119

FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN
64	1.0709E+00	9.6159E+01	65	1.0946E+00	1.0116E+02	66	1.2967E+00	1.1867E+02	67	1.4534E+00	1.3534E+02
68	1.6209E+00	1.5063E+02	69	1.8031E+00	1.6925E+02	70	1.9998E+00	1.8759E+02	71	2.1855E+00	2.0399E+02
72	2.3549E+00	2.1900E+02	73	2.5080E+00	2.3373E+02	74	2.6554E+00	2.4790E+02	75	2.8121E+00	2.6096E+02
76	3.0069E+00	2.8070E+02	77	3.2238E+00	2.9959E+02	78	3.4367E+00	3.1905E+02	79	3.6098E+00	3.3461E+02
80	3.7664E+00	3.4906E+02	81	3.9231E+00	3.6296E+02	82	4.0743E+00	3.7769E+02	83	4.2290E+00	3.9103E+02
84	4.3838E+00	4.0687E+02	85	4.5496E+00	4.2243E+02	86	4.7171E+00	4.3827E+02	87	4.9029E+00	4.5550E+02
88	5.0904E+00	4.7301E+02	89	5.2744E+00	4.9025E+02	90	5.4548E+00	5.0664E+02	91	5.6350E+00	5.2387E+02
92	5.8100E+00	5.4027E+02	93	5.9920E+00	5.5750E+02	94	6.1668E+00	5.7362E+02	95	6.3472E+00	5.9030E+02
96	6.5201E+00	6.0697E+02	97	6.6951E+00	6.2365E+02	98	6.8753E+00	6.4060E+02	99	7.0484E+00	6.5644E+02
100	7.2213E+00	6.7367E+02	101	7.3852E+00	6.8951E+02	102	7.5492E+00	7.0480E+02	103	7.7150E+00	7.2092E+02
104	7.8770E+00	7.3676E+02	105	8.0374E+00	7.5176E+02	106	8.2176E+00	7.6900E+02	107	8.4124E+00	7.8817E+02
108	8.5964E+00	8.3624E+02	109	8.7876E+00	8.2346E+02	110	8.9753E+00	8.4098E+02	111	9.1647E+00	8.5959E+02
112	9.3468E+00	8.7794E+02	113	9.5345E+00	8.9517E+02	114	9.7166E+00	9.1268E+02	115	9.8986E+00	9.2991E+02
116	1.0083E+01	9.4686E+02	117	1.0228E+01	9.5937E+02	118	1.0381E+01	9.7578E+02	119	1.0467E+01	9.8131E+02

ε = 1.06222E+07 FOR FRAMES 70 THROUGH 115

NUMBER OF PLOTS = 3
 LENGTH OF X AXIS = 20 INCHES.
 LENGTH OF Y AXIS = 14 INCHES.

REPRODUCIBILITY OF THE
 ORIGINAL PAGE IS POOR

Problem 3

This example illustrates the input, output, and plots obtained from the torsion test on two tubular specimens. The first tube was instrumented with three strain rosettes (each rosette contained three strain gages) and four LVDT's. A stress-strain curve based on the average absolute values from all $\pm 45^\circ$ oriented strain gages and a torque-twist curve based on the LVDT outputs are plotted in figures 7 and 8, respectively. The second tube (number 4AL) was instrumented with two strain rosettes. A curve based on the sum of the absolute values from the $\pm 45^\circ$ gages (case 9) is plotted in figure 9. The data are expressed in U.S. Customary Units. A listing of the input data follows:

[illegible]

The first data set was obtained from a test on a graphite-epoxy tube whereas the second data set was obtained from a test on an aluminum tube.

The output listing for problem 3 follows:

PROBLEM 3 TORSION TEST

TORSION TEST ON TUBE SPECIMEN
USING GERBER PLOTTER

TUBE NUMBER 4

FRAME	LOAD	SG-1	SG-2
5	0.2914E+01	1.4174E-05	-3.3350E-06
10	1.4128E+02	4.0020E-05	-8.3375E-06
15	3.7384E+02	1.6705E-05	-1.7509E-05
20	5.9544E+02	1.2089E-04	-3.0015E-05
25	8.3594E+02	1.6925E-04	-4.0854E-05
30	1.0898E+03	2.2094E-04	-5.3360E-05

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165	2.1452E+03	4.3772E-04	-1.0589E-04
165	2.4476E+03	5.0192E-04	-1.1589E-04
170	2.7557E+03	5.6111E-04	-1.3340E-04
175	3.0723E+03	6.2781E-04	-1.4591E-04
180	3.3889E+03	6.9285E-04	-1.5841E-04
185	3.6257E+03	7.4037E-04	-1.7000E-04

THICKNESS = 5.3700E-02 OUTER DIAMETER = 3.0194E+00

AVG STRESS-STRAIN POINTS FOR FRAMES 7 THROUGH 75

FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN
7	1.5401E+01	4.8079E+01	8	1.7707E+01	5.7528E+01	9	2.1168E+01	6.9756E+01	10	2.5782E+01	8.3097E+01
11	2.9242E+01	7.6943E+01	12	3.4624E+01	1.1200E+02	13	3.9624E+01	1.2895E+02	14	4.5006E+01	1.4507E+02
15	5.0389E+01	1.0314E+02	16	5.5771E+01	1.8065E+02	17	6.1923E+01	1.9927E+02	18	6.8075E+01	2.1899E+02
19	7.4996E+01	2.3734E+02	20	7.8994E+01	2.5741E+02	21	8.6530E+01	2.7930E+02	22	9.3451E+01	2.9653E+02
23	9.7987E+01	3.1821E+02	24	1.0652E+02	3.3961E+02	25	1.1267E+02	3.6101E+02	26	1.1998E+02	3.8074E+02
27	1.2575E+02	4.0293E+02	28	1.3267E+02	4.2549E+02	29	1.3998E+02	4.4828E+02	30	1.4689E+02	4.6995E+02
31	1.5420E+02	4.9247E+02	32	1.6113E+02	5.1637E+02	33	1.6881E+02	5.3888E+02	34	1.7688E+02	5.6334E+02
35	1.8342E+02	5.8640E+02	36	1.9112E+02	6.1030E+02	37	1.9880E+02	6.3365E+02	38	2.0571E+02	6.5838E+02
39	2.1377E+02	6.8228E+02	40	2.2109E+02	7.0563E+02	41	2.2917E+02	7.3064E+02	42	2.3686E+02	7.5537E+02
43	2.4417E+02	7.8044E+02	44	2.5185E+02	8.0374E+02	45	2.5993E+02	8.2902E+02	46	2.6723E+02	8.5348E+02
47	2.7530E+02	8.7849E+02	48	2.8377E+02	9.0406E+02	49	2.9108E+02	9.2880E+02	50	2.9915E+02	9.5381E+02
51	3.0665E+02	9.7882E+02	52	3.1453E+02	1.0033E+03	53	3.2183E+02	1.0280E+03	54	3.3068E+02	1.0519E+03
55	3.3798E+02	1.0783E+03	56	3.4645E+02	1.1036E+03	57	3.5413E+02	1.1289E+03	58	3.6220E+02	1.1547E+03
59	3.7028E+02	1.1811E+03	60	3.7874E+02	1.2067E+03	61	3.8719E+02	1.2337E+03	62	3.9603E+02	1.2598E+03
63	4.0373E+02	1.2854E+03	64	4.1141E+02	1.3126E+03	65	4.1988E+02	1.3387E+03	66	4.2872E+02	1.3654E+03
67	4.3040E+02	1.3921E+03	68	4.4448E+02	1.4190E+03	69	4.5371E+02	1.4454E+03	70	4.6218E+02	1.4719E+03
71	4.6046E+02	1.4960E+03	72	4.7563E+02	1.5139E+03	73	4.8063E+02	1.5266E+03	74	4.8332E+02	1.5358E+03
75	4.8447E+02	1.5380E+03									

G = 3.1420E+00 FOR FRAMES 7 THROUGH 65

TORQUE TWIST POINTS, FRAMES 7 THROUGH 75

FRAME	TORQUE IN-LBS	TWIST DEG/IN	FRAME	TORQUE IN-LBS	TWIST DEG/IN	FRAME	TORQUE IN-LBS	TWIST DEG/IN	FRAME	TORQUE IN-LBS	TWIST DEG/IN
7	1.1426E+02	1.8359E-03	8	1.3137E+02	2.2133E-03	9	1.5705E+02	2.7207E-03	10	1.9128E+02	3.1796E-03
11	2.1695E+02	3.7222E-03	12	2.5688E+02	4.2360E-03	13	2.9397E+02	4.9076E-03	14	3.3390E+02	5.5009E-03
15	3.7384E+02	6.1870E-03	16	4.1377E+02	6.8387E-03	17	4.5941E+02	7.5224E-03	18	5.0505E+02	8.2823E-03
19	5.5640E+02	9.0248E-03	20	5.9348E+02	9.7439E-03	21	6.4197E+02	1.0504E-02	22	6.9332E+02	1.1232E-02
23	7.4181E+02	1.2004E-02	24	7.9030E+02	1.2838E-02	25	8.3594E+02	1.3638E-02	26	8.9014E+02	1.4434E-02
27	9.3293E+02	1.5273E-02	28	9.8427E+02	1.6096E-02	29	1.0385E+03	1.6933E-02	30	1.0898E+03	1.7798E-02
31	1.1440E+03	1.8662E-02	32	1.1954E+03	1.9578E-02	33	1.2524E+03	2.0439E-02	34	1.3123E+03	2.1313E-02
35	1.3408E+03	2.2230E-02	36	1.4179E+03	2.3131E-02	37	1.4745E+03	2.4032E-02	38	1.5262E+03	2.4916E-02
39	1.5861E+03	2.5786E-02	40	1.6403E+03	2.6716E-02	41	1.7002E+03	2.7644E-02	42	1.7573E+03	2.8571E-02
43	1.8115E+03	2.9503E-02	44	1.8685E+03	3.0431E-02	45	1.9284E+03	3.1431E-02	46	1.9826E+03	3.2273E-02
47	2.0425E+03	3.3272E-02	48	2.1053E+03	3.4215E-02	49	2.1595E+03	3.5209E-02	50	2.2194E+03	3.6123E-02
51	2.2765E+03	3.7095E-02	52	2.3335E+03	3.8051E-02	53	2.3877E+03	3.8972E-02	54	2.4533E+03	3.9959E-02
55	2.5075E+03	4.0894E-02	56	2.5703E+03	4.1865E-02	57	2.6273E+03	4.2874E-02	58	2.6872E+03	4.3872E-02
59	2.7471E+03	4.4844E-02	60	2.8059E+03	4.5808E-02	61	2.8726E+03	4.6864E-02	62	2.9482E+03	4.7872E-02
63	2.9953E+03	4.8869E-02	64	3.0523E+03	4.9906E-02	65	3.1151E+03	5.0901E-02	66	3.1807E+03	5.1950E-02
67	3.2377E+03	5.2494E-02	68	3.2976E+03	5.4082E-02	69	3.3661E+03	5.5117E-02	70	3.4289E+03	5.6141E-02
71	3.4831E+03	5.7070E-02	72	3.5267E+03	5.7798E-02	73	3.5658E+03	5.8355E-02	74	3.5858E+03	5.8708E-02
75	3.5943E+03	5.8776E-02									

SLOPE OF CURVE = 6.13d78E+13 FOR FRAMES 7 THROUGH 65

TUBE NUMBER 441

FRAME	LOAD	S7-1	S7-2
10	3.9311E+02	-8.0040E-05	7.
20	1.1287E+03	-7.4075E-04	-1.7005E-03
30	1.9617E+03	-7.0766E-04	-1.7509E-05
40	2.9304E+03	-5.5945E-04	-7.5012E-05
50	3.8576E+03	-7.3287E-04	-3.0015E-05
60	4.8630E+03	-7.0745E-04	-3.5017E-05
70	5.3397E+03	-1.0522E-03	-4.8357E-05

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220	1.6928E+04	-3.3225E-03	1.7842E-04
230	1.6755E+04	-2.7672E-03	6.3532E-04
240	1.2670E+04	-1.1881E-03	3.1266E-04
250	1.1240E+04	-9.5631E-04	3.6685E-05

THICKNESS = 4.9000E-02 OUTER DIAMETER = 3.0000E+00

AVG STRESS-STRAIN POINTS FOR FRAMES 4 THROUGH 220

FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN	FRAME	STRESS KSI	STRAIN MICRO IN/IN
4	5.5392E-02	4.0853E+01	5	1.4110E-01	5.7528E+01	6	1.4110E-01	7.4203E+01	7	1.4110E-01	9.3797E+01
8	2.2082E-01	1.1547E+02	9	3.5539E-01	1.3924E+02	10	5.2681E-01	1.6633E+02	11	5.2681E-01	1.9301E+02
12	6.5539E-01	2.4219E+02	13	8.6966E-01	2.5179E+02	14	9.9823E-01	2.8138E+02	15	9.9823E-01	3.1265E+02
16	1.1697E+00	3.4142E+02	17	1.3411E+00	3.7560E+02	18	1.4268E+00	4.0895E+02	19	1.6839E+00	4.3855E+02
20	1.6839E+00	4.6815E+02	21	1.7657E+00	4.9691E+02	22	1.8982E+00	5.2568E+02	23	2.1554E+00	5.5736E+02
24	2.2640E+00	5.3988E+02	25	2.3268E+00	6.2156E+02	26	2.5416E+00	6.5157E+02	27	2.4982E+00	6.8451E+02
28	2.7125E+00	7.1619E+02	29	2.7982E+00	7.4870E+02	30	2.9267E+00	7.8497E+02	31	3.1839E+00	8.1832E+02
32	3.3353E+00	8.5043E+02	33	3.4839E+00	8.8586E+02	34	3.4411E+00	9.2004E+02	35	3.6125E+00	9.5339E+02
36	3.8676E+00	9.8799E+02	37	3.8656E+00	1.0222E+03	38	4.0838E+00	1.0568E+03	39	4.2124E+00	1.0914E+03
40	4.3839E+00	1.1256E+03	41	4.5553E+00	1.1602E+03	42	4.7267E+00	1.1952E+03	43	4.7695E+00	1.2314E+03
44	4.9839E+00	1.2635E+03	45	5.0267E+00	1.2940E+03	46	5.1553E+00	1.3332E+03	47	5.2410E+00	1.3694E+03
48	5.4996E+00	1.4065E+03	49	5.7124E+00	1.4390E+03	50	5.7552E+00	1.4762E+03	51	5.8410E+00	1.5116E+03
52	6.1410E+00	1.5470E+03	53	6.2267E+00	1.5825E+03	54	6.3981E+00	1.6183E+03	55	6.4839E+00	1.6542E+03
56	6.6553E+00	1.6892E+03	57	6.7839E+00	1.7246E+03	58	6.9124E+00	1.7600E+03	59	6.9982E+00	1.7967E+03
60	7.2352E+00	1.8301E+03	61	7.3410E+00	1.8672E+03	62	7.5124E+00	1.9018E+03	63	7.6839E+00	1.9381E+03
64	7.7595E+00	1.9739E+03	65	7.8553E+00	2.0102E+03	66	8.1123E+00	2.0460E+03	67	8.1981E+00	2.0831E+03
68	8.4553E+00	2.1206E+03	69	8.4553E+00	2.1556E+03	70	8.7124E+00	2.1931E+03	71	8.7982E+00	2.2293E+03
72	8.9260E+00	2.2640E+03	73	9.0960E+00	2.2944E+03	74	9.3124E+00	2.3353E+03	75	9.3981E+00	2.3716E+03
76	9.4839E+00	2.4071E+03	77	9.7837E+00	2.4458E+03	78	9.8695E+00	2.4829E+03	79	1.0041E+01	2.5192E+03
80	1.0670E+01	2.5546E+03	81	1.0384E+01	2.5921E+03	82	1.0470E+01	2.6275E+03	83	1.0684E+01	2.6621E+03
84	1.0955E+01	2.6393E+03	85	1.0941E+01	2.7351E+03	86	1.1027E+01	2.7726E+03	87	1.1284E+01	2.8101E+03

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188	2.3583E+01	6.6458E+03	189	2.3583E+01	6.6879E+03	190	2.3626E+01	6.7308E+03	191	2.3841E+01	6.7704E+03
192	2.3884E+01	6.8150E+03	193	2.3969E+01	6.8563E+03	194	2.3926E+01	6.8989E+03	195	2.3969E+01	6.9413E+03
196	2.4054E+01	6.9822E+03	197	2.4141E+01	7.0256E+03	198	2.4184E+01	7.0647E+03	199	2.4356E+01	7.1090E+03
200	2.4226E+01	7.1500E+03	201	2.4397E+01	7.1932E+03	202	2.4565E+01	7.2353E+03	203	2.4397E+01	7.2756E+03
204	2.4409E+01	7.3211E+03	205	2.4569E+01	7.3616E+03	206	2.4655E+01	7.4013E+03	207	2.4741E+01	7.4461E+03
208	2.4655E+01	7.4883E+03	209	2.4869E+01	7.5329E+03	210	2.4827E+01	7.5738E+03	211	2.4869E+01	7.6192E+03
212	2.4827E+01	7.6604E+03	213	2.4869E+01	7.7080E+03	214	2.4997E+01	7.7518E+03	215	2.4997E+01	7.7968E+03
216	2.4997E+01	7.8349E+03	217	2.5169E+01	7.8935E+03	218	2.5084E+01	7.9389E+03	219	2.5212E+01	7.9894E+03
220	2.5255E+01	8.0336E+03									

NUMBER OF PLOTS = 3
LENGTH OF X AXIS = 20 INCHES
LENGTH OF Y AXIS = 14 INCHES

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., September 18, 1974.

APPENDIX A

CONVERSION OF U.S. CUSTOMARY UNITS TO SI UNITS

The International System of Units (SI) was adopted by the Eleventh General Conference on Weights and Measures in 1960 (ref. 1). Conversion factors for the units used herein are given in the following table:

Physical quantity	U.S. Customary Unit	Conversion factor (a)	SI Unit (b)
Length	in.	0.0254	meters (m)
Load	lbf	4.448	newtons (N)
Modulus, stress	psi = lbf/in ²	6895	newtons per meter ² (N/m ²)

^aMultiply value given in U.S. Customary Units by conversion factor to obtain equivalent value in SI Units.

^bPrefixes to indicate multiples of units are as follows:

Prefix	Multiple
micro (μ)	10^{-6}
kilo (k)	10^3
mega (M)	10^6
giga (G)	10^9
tera (T)	10^{12}

APPENDIX B

SOURCE PROGRAM LISTING

A listing of the Source Program BECKPLT is presented in this appendix. A description of the significant FORTRAN variables is given in appendix C. The matrix inversion subroutine MATINV used in this program is described in appendix D.

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PROGRAM BECKPLT(INPUT=201,OUTPUT=201,TAPE5=INPUT,TAPE30=201)
C
C PROGRAM TO ASSIST IN THE REDUCTION OF BECKMAN DATA
C
C   DIMENSION TITLE1(4),TITLE2(4),AC2(99),IGAGES(4),DTA(415,20),
C   IX(400), Y(400), TEMPX(4), TEMPY(4)
C   COMMON IOMOVE,IPLOTS,NOPLT(18),XLN  ,YMULT,XMULT ,IUNITS
C
C   READ * PRINT TITLE.
C   READ(5,1) (TITLE1(J),J=1,4)
C   1 FORMAT(4A10)
C   IF(EOF,5) 1000,2
C   2 PRINT 3, (TITLE1(J),J =1,4)
C   3 FORMAT(1H1 4A10 //)
C
C   READ PLOTTER, PEN, INPUT TYPE, SPECIMEN TYPE, TEST TYPE, PLOT INFO, UNITS
C   READ(5,4) IPLT,IPEN,INPT,ISPEC,ITEST,IXSIZE,IYSIZE,IOMOVE,IUNITS
C   4 FORMAT(9I4)
C   IF(IYSIZE.EQ.0) IYSIZE=9
C   IF(IOMOVE.EQ.0) IOMOVE=2
C   IX=IXSIZE
C   XLN = IXSIZE + 0.0
C   YLN = IYSIZE + 0.0
C   IOMOVE=IOMOVE+0.0
C   IF(ITEST.EQ.0 .AND. ISPEC.EQ.0) PRINT 41
C   41 FORMAT(1H ,*COMPRESSION OR TENSION TEST ON FLAT SPECIMEN*)
C   IF(ITEST.EQ.0 .AND. ISPEC.EQ.1) PRINT 42
C   42 FORMAT(1H ,*COMPRESSION OR TENSION TEST ON TUBE SPECIMEN*)
C   IF(ITEST.EQ.1 .AND. ISPEC.EQ.1) PRINT 43
C   43 FORMAT(1H ,*TORSION TEST ON TUBE SPECIMEN*)
C   IF(ITEST.NE.0 .AND. ITES.T.NE.1) PRINT 44,ITEST
C   44 FORMAT(1H ,*INVALID TEST NUMBER, ITEST = *,I4)
C   IF(ITEST.NE.0 .AND. ITES.T.NE.1) STOP
C   IF(ISPEC.NE.0 .AND. ISPEC.NE.1) PRINT 45, ISPEC
C   45 FORMAT(1H ,*INVALID SPECIMEN NUMBER, ISPEC = *,I4)
C   IF(ISPEC.NE.0 .AND. ISPEC.NE.1) STOP
C   IF(ITEST.EQ.1 .AND. ISPEC.EQ.0) PRINT 451
C   451 FORMAT(1H ,*CANNOT HANDLE TCRSION TEST ON FLAT SPECIMEN*)
C   IF(ITEST.EQ.1 .AND. ISPEC.EQ.0) STOP
C   IF(IPLT.EQ.0 .AND. IPEN.EQ.0) PRINT 46
C   46 FORMAT(1H ,*USING CALCCMP PLOTTER WITH BALLPOINT PEN*///)
C   IF(IPLT.EQ.0 .AND. IPEN.EQ.1) PRINT 47
C   47 FORMAT(1H ,*USING CALCOMP PLOTTER WITH LEROY PEN*///)
C   IF(IPLT.NE.0) PRINT 48
C   48 FORMAT(1H ,*USING GERBER PLOTTER*///)
C
C   INITIALIZE PLOTTING ROUTINE.
C   IF(IPLT .EQ. 0) CALL CALCOMP
C   IF(IPLT.NE.0) CALL GERBER
C   IF(IPLT .EQ. 0 .AND. IPEN .NE. 0) CALL LEROY
C   KDUNT=0

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APPENDIX B

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C
C PRINT TITLE ON GRAPH.
  CALL CALPLT(4.,1.2,-3)
  CALL NOTATE(-3.,0.,.25,TITLE1(1),90.,40)
C
C READ + PRINT TITLE OF RUN.
  55 READ(5,1) (TITLE2(JJ), JJ =1,4)
  IF(EDF,5)1000,1100
1100 PRINT 37, (TITLE2(JJ),JJ=1,4)
  37 FORMAT(1H,4A10 ///)
  CALL NOTATE(0.,-1.1,.20,TITLE2(1),0.,40)
C
C READ RUN INFO.
  IF(ITEST.EQ. 0) READ(5,6) JAC,NRL,NRU,INDAVG,IGAGES,MOD,NRLSLP,
  INRUSLP,NOPLT,MORE
  6 FORMAT(4I3,4I2,3I3,18I2,14X,11)
  IF(ITEST.EQ.1) READ(5,61) JAC,NRL,NRU,NROS,INDAVG,MOD,NRLSLP,
  INRUSLP,NOPLT,MORE
  61 FORMAT(8I3,18I2,19X,11)
  NP = NRU-NRL+1
  IF(JAC.GT.20) PRINT 75,JAC
  75 FORMAT(1H0,* TOO MANY CHANNELS, JAC = *,I4)
  IF(JAC.GT.20) GO TO 1000
C
C READ IN DATA.
  IF(INPT.EQ. 0) CALL RDTAPE(JAC,NRL,NRU,MD,DTA)
  IF(INPT.EQ. 1) CALL RDCARD(JAC,NRL,NRU,MD,DTA)
  IF(INPT.EQ. 2) CALL RDCCELL(JAC,NRL,NRU,MD,DTA)
  KNTRUN=0
C
C READ IN SECTIONAL DATA.
  IF(ITEST.EQ. 0) READ(5,8) THICK,WIDTH,SCFAC,RMAXSN
  8 FORMAT(4F12.4)
  IF(ITEST.EQ. 1) READ(5,81) THICK,WIDTH,RLENGTH,ALENGTH,SCFAC,
  IRMAXSN
  81 FORMAT(6F12.4)
  IF(SCFAC.EQ.0) SCFAC=1.
  82 IF(NP.LT.1) PRINT 76, NRL,NRU
  76 FORMAT(1H0,* LAST FRAME TO BE PLOTTED LESS THAN FIRST FRAME*, /,
  1* FIRST FRAME = *,I3,6X,*LAST FRAME = *,I3, / , * WILL GO TO NEXT
  2PLOT*)
  IF(NP.LT.1) GO TO 50
C
C USE TYPE OF SPECIMEN + SECTIONAL DATA TO COMPUTE STRESSES
C AND STORE IN Y ARRAY.
  CALL LJADY(THICK,WIDTH,SCFAC,ISPEC,ITEST,NRL,NRU,Y,DTA,FAC,YMULT,
  1IUNITS,KNTRUN)
  IF(MOD.NE.1) GO TO 751
  IF(MOD.EQ.1 .AND. NRLSLP.EQ. 0) NRLSLP=NRL
  IF(MOD.EQ.1 .AND. NRUSLP.EQ.0) NRUSLP=NRU
  IF(NRLSLP.GT.NRUSLP) PRINT 613,NRLSLP,NRUSLP
  613 FORMAT(1H0,* FIRST FRAME FOR SLOPE GREATER THAN LAST FRAME FOR SLO
  1PE.*, / , * FIRST FRAME = *,I4,6X,* LAST FRAME = *,I4, / , * WILL NOT FI
  2ND SLOPE.*)
  IF(NRLSLP.GT.NRUSLP) MOD=0
  IF(MOD.EQ.0) GO TO 751
  IF(NRLSLP.LT.NRL .OR. NRLSLP.GT.NRU) PRINT 611,NRLSLP
  611 FORMAT(1H0,* FIRST FRAME FOR SLOPE INVALID.*, / , * FIRST FRAME =
  1*,I4, / , * WILL USE FIRST FRAME PLOTTED.*)
  IF(NRLSLP.LT.NRL .OR. NRLSLP.GT.NRU) NRLSLP=NRL

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APPENDIX B

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        IF(NRUSLP.LT.NRL .OR. NRUSLP.GT.NRU) PRINT 612,NRUSLP
612  FORMAT(1H0,* LAST FRAME FOR SLOPE INVALID.*, / , * LAST FRAME = *,
        1I4,/* WILL USE LAST FRAME PLOTTED.*)
        IF(NRUSLP.LT.NRL .OR. NRUSLP.GT.NRU) NRUSLP=NRU
751  CONTINUE

C
C  SET X + Y SCALES.
      XMULT=1.0
      IF(RMAXSN .LT. .1) XMULT=10.**6
      TEMPX(1)=0.
      TEMPX(2)=RMAXSN*XMULT
      IF(ISPEC.EQ.1 .AND. ITEST.EQ.1 .AND. INDAVG.NE.0) TEMPX(2)=2*TEMPX
      I(2)
      TEMPY(1)=0.
      TEMPY(2)=Y(NP)
      DO 761 I=1,NP
761  IF(Y(I).GT.TEMPY(2)) TEMPY(2)=Y(I)

      IPLOTS=1
      IF(ITEST .EQ. 0 .AND. INDAVG .EQ. 0) IPLOTS=JAC-1
      IF(ITEST .EQ. 0 .AND. INDAVG .EQ. 1) IPLOTS=JAC
      IF(ISPEC .EQ. 1 .AND. ITEST .EQ. 1 .AND. INDAVG .EQ. 0) IPLOTS =
13*NROS
      IF(ISPEC .EQ. 1 .AND. ITEST .EQ. 1 .AND. INDAVG .EQ. 3) IPLOTS =
13*NROS+1
      IF(IX.EQ.0 .AND. ITEST.EQ.0) XLN=OMOVE*JAC
      IF(IX.EQ.0 .AND. ITEST.EQ.1) XLN=OMOVE*(3.*NRUS+1.)*NROS
      IXSIZE=XLN
      XXLN = XLN-OMOVE*(IPLOTS-1)
      IF(XXLN .LT. OMOVE) XXLN=OMOVE
      IF(ITEST.EQ.1 .AND. (INDAVG.EQ.0.OR.INDAVG.EQ.3))XXLN=OMOVE
      CALL ASCALE(TEMPX,XXLN,2,1,10.0)
      CALL ASCALE(TEMPY,YLN,2,1,10.0)
      X(NP+1)=0.
      X(NP+2)=TEMPX(4)
      XSC=TEMPX(4)
      Y(NP+1)=0.
      Y(NP+2)=TEMPY(4)
      YSC=TEMPY(4)

C
C  DRAW THE X+Y AXES.
      IF(IUNITS.NE.0) GO TO 695
      IF(ITEST .EQ. 0 .AND. YMULT .EQ. .001) CALL AXES(0.,0.,90.,YLN,0.,
1YSC,1.,0.,10HSTRESS,KSI,.25,10)
      IF(ITEST .EQ. 0 .AND. YMULT .EQ. 1.) CALL AXES(0.,0.,90.,YLN,0.,
1YSC,1.,0.,10HSTRESS,PSI,.25,10)
      IF(ITEST .EQ. 1 .AND. YMULT .EQ. .001) CALL AXES(0.,0.,90.,YLN,0.,
1YSC,1.,0.,16HSHEAR STRESS,KSI,.25,16)
      IF(ITEST .EQ. 1 .AND. YMULT .EQ. 1.) CALL AXES(0.,0.,90.,YLN,0.,
1YSC,1.,0.,16HSHEAR STRESS,PSI,.25,16)
      IF((INDAVG .NE.2) .AND. (ITEST .NE. 1 .OR. INDAVG .NE. 1))GO TO 68
      IF((ITEST.EQ.0 .OR. INDAVG.EQ.0 .OR. INDAVG.EQ.3) .AND. XMULT.EQ.1
1) CALL AXES(0.,0.,0.,XLN,0.,XSC,1.0,0., 7HSTRAIN ,.25,-12)
      IF((ITEST.EQ.1 .AND. (INDAVG.EQ.1.OR.INDAVG.EQ.2)) .AND. XMULT.EQ.
11) CALL AXES(0.,0.,0.,XLN,0.,XSC,1.0.,13HSHEAR STRAIN ,.25,
2-18)
      IF(XMULT .EQ. 1)GO TO 69
      CALL AXES(0.,0.,0.,XLN,0.,XSC,-1.,0.,1H ,.25,-1)

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      IF( ITEST.EQ.0 .OR. (INDAVG.EQ.0.OR.INDAVG.EQ.3))CALL NOTATE(XLN/2.
1,-.7,.25,18HSTRAIN,MICRO IN/IN,0.,18)
      IF( ITEST.EQ.1 .AND. (INDAVG.EQ.1 .OR. INDAVG.EQ.2)) CALL NOTATE(
1XLN/2.,-.7,.25,24HSHEAR STRAIN,MICRO IN/IN,0.,24)
      GO TO 69
68 CALL DASHLN(0.,0.,XLN,0.,XLN)
      PLACE=IXSIZE/4
      CALL DASHLN(PLACE, -.6,PLACE,0.,.6)
      CALL DASHLN(PLACE+1.,-.6,PLACE+1.,0.,.6)
      CALL PARROW(PLACE-.3,-.30,PLACE,-.30,1)
      CALL PARROW(PLACE+1.3,-.30,PLACE+1.,-.30,1)
      CALL NUMBER(PLACE+.2,-.37,.14,XSC/XMULT,0.,4)
      IF( ITEST.EQ.0) CALL NOTATE(XLN/2.,-.8,.25, 7HSTRAIN      ,0.,12)
      IF( ITEST.EQ.1) CALL NOTATE(XLN/2.,-.8,.25,13HSHEAR STRAIN  ,
10.,18)
      GO TO 69
695 IF( ITEST.EQ.0 .AND. YMULT.EQ.1.) CALL AXES(0.,0.,90.,YLN,0.,YSC,1.
1,0., 9HSTRESS,PA,.25,9)
      IF( ITEST.EQ.0 .AND. YMULT.EQ. .001) CALL AXES(0.,0.,90.,YLN,0.,YSC
1,1.,0.,10HSTRESS,KPA,.25,10)
      IF( ITEST.EQ.0 .AND. YMULT.EQ. 10.**(-6)) CALL AXES(0.,0.,90.,YLN,0
1.,YSC,1.,0.,10HSTRESS,MPA,.25,10)
      IF( ITEST.EQ.0 .AND. YMULT.EQ. 10.**(-9)) CALL AXES(0.,0.,90.,YLN,0
1.,YSC,1.,0.,10HSTRESS,GPA,.25,10)
      IF( ITEST.EQ.0 .AND. YMULT.EQ. 10.**(-12)) CALL AXES(0.,0.,90.,YLN,
10.,YSC,1.,0.,10HSTRESS,TPA,.25,10)
      IF( ITEST.EQ.1 .AND. YMULT.EQ.1) CALL AXES(0.,0.,90.,YLN,0.,YSC,1.,
10.,19HSHEAR STRESS,PA,.25,15)
      IF( ITEST.EQ.1 .AND. YMULT.EQ. .001) CALL AXES(0.,0.,90.,YLN,0.,YSC
1,1.,0.,16HSHEAR STRESS,KPA,.25,16)
      IF( ITEST.EQ.1 .AND. YMULT.EQ. 10.**(-6)) CALL AXES(0.,0.,90.,YLN,0
1.,YSC,1.,0.,16HSHEAR STRESS,MPA,.25,16)
      IF( ITEST.EQ.1 .AND. YMULT.EQ. 10.**(-9)) CALL AXES(0.,0.,90.,YLN,0
1.,YSC,1.,0.,16HSHEAR STRESS,GPA,.25,16)
      IF( ITEST.EQ.1 .AND. YMULT.EQ. 10.**(-12)) CALL AXES(0.,0.,90.,YLN,
10.,YSC,1.,0.,16HSHEAR STRESS,TPA,.25,16)
      IF((INDAVG.NE.2) .AND. ( ITEST.NE.1 .OR. INDAVG.NE.1)) GO TO 685
      IF( ITEST.EQ.0 .OR. INDAVG.EQ.0 .OR. INDAVG.EQ.3) .AND. XMULT.EQ.1
1) CALL AXES(0.,0.,0.,XLN,0.,XSC,1.0,0., 7HSTRAIN      ,.25,-10)
      IF( ITEST.EQ.1 .AND. (INDAVG.EQ.1.OR.INDAVG.EQ.2)) .AND. XMULT.EQ.
11) CALL AXES(0.,0.,0.,XLN,C.,XSC,1.,0.,13HSHEAR STRAIN  ,.25,-16
2)
      IF(XMULT.EQ.1)GO TO 69
      CALL AXES(0.,0.,0.,XLN,0.,XSC,-1.,0.,1H ,.25,-1)
      IF( ITEST.EQ.0 .OR. (INDAVG.EQ.0.OR.INDAVG.EQ.3))CALL NOTATE(XLN/2.
1,-.7,.25,18HSTRAIN,MICRO M/M ,0.,18)
      IF( ITEST.EQ.1 .AND. (INDAVG.EQ.1 .OR. INDAVG.EQ.2)) CALL NOTATE(
1XLN/2.,-.7,.25,24HSHEAR STRAIN,MICRO M/M ,0.,24)
      GO TO 69
685 CALL DASHLN(0.,0.,XLN,0.,XLN)
      PLACE=IXSIZE/4
      CALL DASHLN(PLACE, -.6,PLACE,0.,.6)
      CALL DASHLN(PLACE+1.,-.6,PLACE+1.,0.,.6)
      CALL PARROW(PLACE-.3,-.3,PLACE,-.3,1)
      CALL PARROW(PLACE+1.3,-.3,PLACE+1.,-.3,1)
      CALL NUMBER(PLACE+.2,-.37,.14,XSC/XMULT,0.,4)
      IF( ITEST.EQ.0) CALL NOTATE(XLN/2.,-.8,.25, 7HSTRAIN      ,0.,10)
      IF( ITEST.EQ.1) CALL NOTATE(XLN/2.,-.8,.25,13HSHEAR STRAIN  ,0.,
110)
69 CALL DGRID(0.,0.,1.,1.,IXSIZE,IYSIZE,0.1)
      KOUNT=KOUNT+1

```

APPENDIX B

```

C
C  LOAD X ARRAY, PRINT, AND PLOT.
      IF(ITEST .EQ. 0 .AND. INDAVG .NE. 2)CALL COMPIND(IGAGES,MOD,NRLSLP
1,NRUSLP,JAC,NRL,NRU,NP,X,Y,XMULT,INDAVG,IXSIZE,DTA,YN,ISPEC,YMULT
2,IUNITS)
      IF(ITEST .EQ. 0 .AND. INDAVG .EQ. 2)CALL COMPAVG(IGAGES,MOD,NRLSLP
1,NRUSLP,JAC,NRL,NRU,NP,X,Y,XMULT,DTA,YN,ISPEC,YMULT,IUNITS)
      IF(ISPEC .EQ. 1 .AND. ITEST .EQ. 1 .AND. (INDAVG .EQ. 0 .OR.
1INDAVG .EQ. 3))CALL TORIND(IGAGES,MOD,NRLSLP,NRUSLP,JAC,NROS,NRL,
2NRU,NP,X,Y,XMULT,INDAVG,IXSIZE,DTA,YN,XSC,RMAXSN,YMULT,IUNITS)
      IF(ISPEC .EQ. 1 .AND. ITEST .EQ. 1 .AND. (INDAVG .EQ. 1 .OR.
1INDAVG .EQ. 2))CALL TORAVG(IGAGES,MOD,NRLSLP,NRUSLP,JAC,NROS,NRL,
2NRU,NP,X,Y,XMULT,INDAVG,IXSIZE,DTA,YN,XSC,YSC,FAC,YMULT,ALENGTH,
3RLENGTH,IUNITS)
      IF(ITEST.EQ.1 .AND. INDAVG.EQ.2) KOUNT=KOUNT+1
      IF(MOD.EQ.2) KOUNT=KOUNT+1
C
C  GO TO NEW GRAPH, NEW RUN.
50  IF(MORE.EQ.0 .AND. MD.EQ.9999) GO TO 1000
      CALL CALPLT(XLN+6.,0.,-3)
      PRINT 1200
1200 FORMAT(1H1)
      IF(MORE.EQ.0) GO TO 55
      KNTRUN=KNTRUN+1
      IF(ITEST.EQ.0) READ(5,700)NRL,NRU,INDAVG,IGAGES,MOD,NRLSLP,NRUSLP,
1NOPLT,MORE
700  FORMAT(3I3,4I2,3I3,18I2,17X,11)
      IF(ITEST.EQ.1) READ(5,701) NRL,NRU,NROS,INDAVG,MOD,NRLSLP,NRUSLP,
1NOPLT,MORE
701  FORMAT(7I3,18I2,22X,11)
      NP=NRU-NRL+1
      GO TO 82
1000 CALL CALPLT(0.,0.,999)
      PRINT 1025, KOUNT
1025 FORMAT(/// 1H * NUMBER OF PLOTS = * I3)
      PRINT 1026, IXSIZE,IYSIZE
1026 FORMAT(1H *LENGTH OF X AXIS = * I4 * INCHES* /1H *LENGTH OF Y AX
1IS = * I4 * INCHES*)
      END

```

SUBROUTINE RDTAPE(JAC,NRL,NRU,MD,DTA)

```

C
C  READS BECKMAN DATA FROM MAGNETIC TAPE IN FORMAT 2.
C
      DIMENSION AC2(99),DTA(415,20)
      PRINT 198
198  FORMAT(1H0,*          FRAME      LOAD          SG-1          SG-2          *)
      N=2
      NP=NRU-NRL+1
100  READ(30) MD,IFM,ISP,IFRA,TIM,TV,IFAC,ITST,MRN,MSN,DC6,DC7,DC8,DC9,
1DC10,AC2

```


APPENDIX B

```

C
C CHECK FOR END OF RUN.
C   IF(MD .EQ. 8888 .OR. MD .EQ. 9999) GO TO 199
C
C PRINT EVERY FIFTH OR TENTH FRAME.
C   IF((NP .LE. 100 .AND. N/5*5 .EQ. N) .OR. (N/10*10 .EQ. N)) PRINT
C     1101, IFRA,(AC2(K),K=1,3)
C   101 FORMAT(1H0,112,3E12.4)
C
C STORE DATA IN ARRAY DTA.
C   DO 103 J=1,JAC
C   103 DTA(IFRA,J)=AC2(J)
C     N=N+1
C     GO TO 100
C   199 RETURN
C     END

```

```

      SUBROUTINE RDCELL(JAC,NRL,NRU,MD,DTA)
C
C READS DATA FROM DATA FILE CN DATA CELL--DATA ON TAPE30
C
C   DIMENSION DTA(415,20)
C   PRINT 198
C   198 FORMAT(1H0,*      FRAME      LOAD      SG-1      SG-2      *)
C     N=2
C     NP=NRU-NRL+1
C   400 READ(30,401) ITST,MRN,MD,IFRA,ISQ
C   401 FORMAT(3112,24X,112,18)
C CHECK FOR END OF RUN.
C   IF(MD .EQ. 8888 .OR. MD .EQ. 9999) GO TO 410
C READ DATA INTO ARRAY DTA.
C   DO 411 J=1,18,6
C     JJ=J+5
C   411 READ(30,402) (DTA(IFRA,K),K=J,JJ),ISQ
C   402 FORMAT(6E12.4, 18)
C
C PRINT EVERY FIFTH OR TENTH FRAME.
C   IF((NP .LE. 100 .AND. N/5*5 .EQ. N) .OR. (N/10*10 .EQ. N)) PRINT
C     1403, IFRA,(DTA(IFRA,K),K=1,3)
C   403 FORMAT(1H0,112,3E12.4)
C     N=N+1
C     GO TO 400
C   410 RETURN
C     END

```

APPENDIX B

```

      SUBROUTINE LOADY(THICK,WIDTH,SCFAC,ISPEC,ITEST,NRL,NRU,Y,DTA,FAC,
      1 YMULT,IUNITS,KNTRUN)
C   COMPUTES STRESSES AND LOADS Y ARRAY FOR EACH SPEC + TEST TYPE.
C
      DIMENSION Y(400),DTA(415,20)
      IF(KNTRUN.NE.0) GO TO 19
      PI=3.14159
      IF(ISPEC.EQ.0) FAC=THICK*WIDTH
      IF(ISPEC.EQ.1.AND. ITES.T.EQ.0) FAC=PI*(WIDTH-THICK)*THICK
      IF(ISPEC.EQ.1.AND. ITES.T.EQ.1) FAC=2*PI*(((WIDTH-THICK)/2)**2
      1)*THICK
      IF(ISPEC.EQ.0) PRINT 191, THICK,WIDTH
191  FORMAT(1H0,* THICKNESS = *,E12.4,6X,* WIDTH = *,E12.4)
      IF(ISPEC.EQ.1) PRINT 192, THICK, WIDTH
192  FORMAT(1H0,* THICKNESS = *,E12.4,6X,* OUTER DIAMETER = *,E12.4)
C   IF STRESSES TOO LARGE, DIVIDE BY 1000.
19  YMULT=1.0
      RMAXLD=ABS(DTA(NRU,1))
      DO 196 I=NRL,NRU
196  IF(ABS(DTA(I,1)).GT.RMAXLD) RMAXLD=ABS(DTA(I,1))
      RMAXSS=RMAXLD/FAC
      IF(RMAXSS.GT. 1000) YMULT=.001
      IF(IUNITS.EQ.0) GO TO 193
      IF(RMAXSS*.001.GT. 1000) YMULT=10.**(-6)
      IF(RMAXSS*(10.**(-6)).GT. 1000) YMULT=10.**(-9)
      IF(RMAXSS*(10.**(-9)).GT. 1000) YMULT=10.**(-12)
C   PUT STRESSES IN Y ARRAY.
193 DO 200 I=NRL,NRU
200 Y(I-NRL+1)=(DTA(I,1)/FAC)*YMULT*SCFAC
      RETURN
      END

```

```

      FUNCTION POLYE1(X,M,C)
      DATA BIG/0.7777777777777777/
      DIMENSION C(M)
      IF(M-1)10,11,12
12  N=M-1
      POLYE1=C(1)
      DO20 I=1,N
20  POLYE1=X*POLYE1+C(I+1)
      RETURN
10  POLYE1=BIG
      RETURN
11  POLYE1=C(1)
      RETURN
      END

```

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

APPENDIX B

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      SUBROUTINE RDCARD(JAC,NRL,NRU,MD,DTA)
C
C   READS DATA FROM PUNCHED CARDS.
C
      DIMENSION DTA(415,20)
      PRINT 198
198  FORMAT(1H0,*          FRAME      LOAD          SG-1          SG-2          *)
      N=2
      NP=NRU-NRL+1
500  DO 511 J=1,JAC,6
      JJ=J+5
      IF(J.EQ.1) READ(5,501) IFRA,(DTA(IFRA,K),K=J,JJ),MD
501  FORMAT(14,6E12.4,14)
      IF(J.NE.1) READ(5,502) (DTA(IFRA,K),K=J,JJ),MD
502  FORMAT(6E12.4,14)
511  CONTINUE
C   CHECK FOR END OF RUN.
      IF(MD .EQ. 8888 .OR. MD .EQ. 9999) GO TO 510
C   PRINT EVERY FIFTH OR TENTH FRAME.
      IF((NP .LE. 100 .AND. N/5*5 .EQ. N) .OR. (N/10*10 .EQ. N)) PRINT
        1503, IFRA,(DTA(IFRA,K),K=1,3)
503  FORMAT(112,3E12.4)
      N=N+1
      GO TO 500
510  RETURN
      END

      SUBROUTINE COMBIND(IGAGES,MOD,NRLSLP,NRUSLP,JAC,NRL,NRU,NP,X,Y,
        IXMULT,INDAVG,IXSIZE,DTA,YLN,ISPEC,YMULT,IUNITS)
C
C   LOADS X ARRAY FOR COMP TEST, INDIV GAGE PLOT, AND CALLS PRTPLOT.
C
      DIMENSION IGAGES(4),X(400),Y(400),DTA(415,20)
      COMMON CMOVE,IPLUTS,NOPLT(18),XLN,AY,BX,IUTS
      DO 122 IGAG=2,JAC
      DO 124 K=1,18
124  IF(IGAG-1.EQ.NOPLT(K)) GO TO 122
      DO 121 I=NRL,NRU
121  X(I-NRL+1)=ABS(DTA(I,IGAG)*XMULT)
      CALL PRTPLOT(ISPEC,0,INDAVG,IGAGES,IGAG,NRL,NRU,NP,X,Y,YLN)
      IF(IGAG .LT. JAC) CALL CALPLT(CMOVE,0.,-3)
122  CONTINUE
      IF(INDAVG .EQ. 0) GO TO 123
      DO 125 K=1,18
      IF(JAC-1.EQ.NOPLT(K)) GO TO 126
125  CONTINUE
      CALL CALPLT(CMOVE,0.,-3)
126  CALL COMPAVG(IGAGES,MOD,NRLSLP,NRUSLP,JAC,NRL,NRU,NP,X,Y,XMULT,DTA
        1,YLN,ISPEC,YMULT,IUNITS)
123  RETURN
      END

```

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SUBROUTINE COMPAVG(IGAGES,MCD,NRLSLP,NRUSLP,JAC,NRL,NRU,NP,X,Y,
1XMULT,DTA,YN,ISPEC,YMULT,IUNITS)

```

C
C LOADS X ARRAY FOR COMP TEST, AVG PLOT, AND CALLS PRTPLOT.
C IF MOD=1, CALLS SLP.
C
  DIMENSION IGAGES(4),X(400),Y(400),DTA(415,20)
  COMMON UMOVE,IPLCTS,NOPLT(18),XLN,AY,BX,IUTS
C FIND NUMBER OF GAGES TO BE AVERAGED.
  N=0
  DO 131 I=1,4
    IF(IGAGES(I) .NE. 0) N=N+1
131 CONTINUE
C FIND AVERAGES + PLOT.
  DO 132 I=1,NP
132 X(I)=0
  DO 135 J=1,4
    IF(IGAGES(J) .EQ. 0) GO TO 135
    DO 134 I=NRL,NRU
      IGAGESJ=IGAGES(J)
134 X(I-NRL+1)=X(I-NRL+1)+ABS(DTA(I,IGAGESJ+1)*XMULT/N)
135 CONTINUE
  CALL PRTPLOT(ISPEC,0,2,IGAGES,0,NRL,NRU,NP,X,Y,YN)
C IF MOD=1, FIND + PRINT SLOPE.
  IF(MOD .EQ. 0) GO TO 139
  IF(MOD .EQ. 2) CALL PROPLIM(X,Y,NRL,NRU,NP,XMULT,YMULT,IUNITS)
  IF(MOD .EQ. 2) GO TO 139
  DO 1531 I=NRLSLP,NRUSLP
    X(I-NRLSLP+1)=X(I-NRL+1)
1531 Y(I-NRLSLP+1)=Y(I-NRL+1)
    NPSLP=NRUSLP-NRLSLP+1
    CALL SLP(X,Y,XBR,YBR,EX,NPSLP,XMULT,YMULT)
    PRINT 158,EX,NRLSLP,NRUSLP
158 FORMAT(/ / 5X,* E = *,E12.5,4X,* FOR FRAMES*,I4,* THROUGH*,I4 //)
139 RETURN
  END

```

SUBROUTINE TORIND(IGAGES,MCD,NRLSLP,NRUSLP,JAC,NRCS,NRL,NRU,NP,X,Y,
1XMULT,INDAVG,IXSIZE,DTA,YN,XSC,RMAXSN,YMULT,IUNITS)

```

C
C LOADS X ARRAY FOR TUBE SPEC, TORSION TEST, INDIV GAGE PLOT, AND CALLS
C PRTPLOT.
C
  DIMENSION IGAGES(4),X(400),Y(400),DTA(415,20)
  COMMON UMOVE,IPLCTS,NOPLT(18),XLN,AY,BX,IUTS
  IGAG=3
160 DO 166 K=1,18
166 IF(IGAG-1.EQ.NOPLT(K)) GO TO 167
  DO 161 I=NRL,NRU
161 X(I-NRL+1)=ABS(DTA(I,IGAG)*XMULT)
  CALL PRTPLOT(1,1,INDAVG,IGAGES,IGAG,NRL,NRU,NP,X,Y,YN)
  IF(IGAG/3*3 .EQ. IGAG) GO TO 162

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      IGAG=IGAG+2
      IF(IGAG.GT.3*NROS+1) GO TO 164
      GO TO 163
162  IGAG=IGAG-1
163  CALL CALPLT(OMOVE,0.,-3)
      IF(IGAG.NE.3 .AND. IGAG/3*3.EQ.IGAG) CALL CALPLT(1.,0.,-3)
      GO TO 160
167  IF(IGAG/3*3.EQ.IGAG) GO TO 168
      IGAG=IGAG+2
      IF(IGAG.GT.3*NROS+1) GO TO 164
      GO TO 160
168  IGAG=IGAG-1
      GO TO 160
164  IF(INDAVG .EQ. 0) GO TO 169
      DO 1641 K=1,18
      IF(3*NROS+1.EQ.NOPLT(K)) GO TO 1642
1641  CONTINUE
      CALL CALPLT(OMOVE,0.,-3)
1642  DO 165 I=NRL,NRU
165  X(I-NRL+1)=(ABS(DTA(I,2))+ABS(DTA(I,4)))*XMULT
      CALL PRTPLT(1,1,INCAVG,IGAGES,-1,NRL,NRU,NP,X,Y,YLN)
C   IF MOD=1, FIND + PRINT SLOPE.
      IF(MOD .EQ. 0) GO TO 169
      IF(MOD.EQ.2) CALL PROPLIM(X,Y,NRL,NRU,NP,XMULT,YMULT,IUNITS)
      IF(MOD.EQ.2) GO TO 169
      DO 1531 I=NRLSLP,NRUSLP
      X(I-NRLSLP+1)=X(I-NRL+1)
1531  Y(I-NRLSLP+1)=Y(I-NRL+1)
      NPSLP=NRUSLP-NRLSLP+1
      CALL SLP(X,Y,XBR,YBR,EX,NPSLP,XMULT,YMULT)
      PRINT 139,EX,NRLSLP,NRUSLP
139  FORMAT(/ / 5X,* G = *,E12.5,4X,* FOR FRAMES*,I4,* THROUGH*,I4 / /)
169  RETURN
      END

```

SUBROUTINE TORAVG(IGAGES,MCD,NRLSLP,NRUSLP,JAC,NROS,NRL,NRU,NP,X,Y
1,XMULT,INDAVG,IXSIZE,DTA,YLN,XSC,YSC,FAC,YMULT,ALENGTH,RLENGTH,
ZIUNITS)

```

C
C   LOADS X ARRAY FOR TUBE SPEC, TORSION TEST, AVG PLOT, AND CALLS
C   PRTPLT. IF MOD=1, CALLS SLP.
C
      DIMENSION IGAGES(4),X(400),Y(400),DTA(415,20),HOLOX(4),HOLOY(4)
      COMMON OMOVE,IPLOTS,NOPLT(18),XLN,AY,BX,IUTS
      DO 171 I=1,NP
171  X(I)=0
      N=0
      DO 172 J=1,NROS
      DO 161 K=1,18
      IF(3*J-2.EQ.NOPLT(K).OR.3*J.EQ.NOPLT(K)) N=N+1
      IF(3*J-2.EQ.NOPLT(K).OR.3*J.EQ.NOPLT(K)) GO TO 172
161  CONTINUE

```

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```

DO 163 I=NRL,NRU
163 X(I-NRL+1)=X(I-NRL+1)+(ABS(DTA(I,3*J-1))+ABS(DTA(I,3*J+1)))*XMULT
172 CONTINUE
DO 162 I=NRL,NRU
162 X(I-NRL+1)=X(I-NRL+1)/(NRCS-N)
CALL PRTPLT(1,1,INDAVG,IGAGES,0,NRL,NRU,NP,X,Y,YLN)
C IF MOD=1, FIND + PRINT SLOPE.
IF(MOD.EQ.0)GO TO 175
IF(MOD.EQ.2) CALL PROPLIM(X,Y,NRL,NRU,NP,XMULT,YMULT,IUNITS)
IF(MOD.EQ.2)GO TO 175
DO 1531 I=NRLSLP,NRUSLP
X(I-NRLSLP+1)=X(I-NRL+1)
1531 Y(I-NRLSLP+1)=Y(I-NRL+1)
NPSLP=NRUSLP-NRLSLP+1
CALL SLP(X,Y,XBR,YBR,EX,NPSLP,XMULT,YMULT)
PRINT 138,EX,NRLSLP,NRUSLP
138 FORMAT(/ / 5X,* G = *,E12.5,4X,* FOR FRAMES*,I4,* THROUGH*,I4 / /)
C IF INDAVG=1, PLOT TWIST CURVES.
175 IF(INDAVG.NE.2)GO TO 179
PI=3.14159
MIN=JAC-3
MAX=MIN+3
C MAKE NEW GRAPH.
XLM=XLN
IF(XLM.LT.9.) XLM=9.
CALL CALPLT(XLM+6.,0.,-3)
HOLDY(1)=0.
HOLDY(2)=DTA(NRU,1)
CALL ASCALE(HOLDY,YLN,2,1,10.0)
YSC2=HOLDY(4)
Y(NP+2)=YSC2
HOLDX(1)=0.
HOLDX(2)= (ABS(DTA(NRU,MIN))+ABS(DTA(NRU,MIN+1))-ABS(DTA(NRU,
MIN+2))-ABS(DTA(NRU,MIN+3)))/(2*ALENGTH*RLENGTH)
IF(IUNITS.EQ.0) HOLDX(2) = HOLDX(2) *180./PI
CALL ASCALE(HOLDX,XLN,2,1,10.0)
XSC2=HOLDX(4)
X(NP+2)=XSC2
IF(IUNITS.EQ.0) CALL AXES(0.,0.,90.,YLN,0.,YSC2,-1.,0.,12HTORQUE,I
IN-LB,.25,12)
IF(IUNITS.EQ.1) CALL AXES(0.,0.,90.,YLN,0.,YSC2,-1.,0.,15HTORQUE,N
EWTON-M,.25,15)
CALL AXES(0.,0.,0.,XLN,0.,XSC2,1.,0.,1H,0.,-1)
CALL NUMBER(-1.5/28.,-.25,.1875,0.,0.,-1)
DO 1771 I=1,IXSIZE
PLACE=I+0.
1771 CALL NUMBER(PLACE-15./56.,-.25,.1875,XSC2*PLACE,0.,4)
IF(IUNITS.EQ.0) CALL NCTATE(XLN/2.-1.3,-.75,.25,12HTWIST,DEG/IN,0.
1,12)
IF(IUNITS.EQ.1) CALL NCTATE(XLN/2.-1.3,-.75,.25,11HTWIST,RAD/M,0.,
111)
IYSIZE=YLN
CALL DGRID(0.,0.,1.,1.,IXSIZE,IYSIZE,0.1)
C LOAD X ARRAY.
DO 176 I=NRL,NRU
X(I-NRL+1) = (ABS(DTA(I,MIN))+ABS(DTA(I,MIN+1))-ABS(DTA(I,MIN+
12))-ABS(DTA(I,MIN+3)))/(2.*ALENGTH*RLENGTH)
IF(IUNITS.EQ.0) X(I-NRL+1)= X(I-NRL+1) *180./PI
176 CONTINUE

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C   LOAD Y ARRAY.
      DO 177 I=NRL,NRU
177  Y(I-NRL+1)=ABS(DTA(I,1))
C   PRINT + PLOT
      CALL PRTPLT(1,1,INDAVG,IGAGES,-2,NRL,NRU,NP,X,Y,YLEN)
      IF(MOD.NE.1) GO TO 179
      DO 1532 I=NRLSLP,NRUSLP
      X(I-NRLSLP+1)=X(I-NRL+1)
1532  Y(I-NRLSLP+1)=Y(I-NRL+1)
      NPSLP=NRUSLP-NRLSLP+1
      CALL SLP(X,Y,XBR,YBR,EX,NPSLP,XMULT,YMULT)
      PRINT 154,EX,NRLSLP,NRUSLP
154  FORMAT(/ /5X*SLOPE OF CURVE = * E12.5,4X,*FOR FRAMES*
1    14 * THROUGH* 14 //)
179  RETURN
      END

```

SUBROUTINE PRTPLT(ISPEC, ITEST, INDAVG, IGAGES, IGAG, NRL, NRU, NP, X, Y,
IYLEN)

```

C
C   PRINTS + PLOTS POINTS FROM X,Y ARRAYS.
C
      DIMENSION IGAGES(4), X(400), Y(400)
      DIMENSION NOPLT2(18), IFRAM(400)
      COMMON UMDOVE, IPLCTS, NOPLT(18), XLN, AY, BX, IUTS
      IXM = 1
      IYM = 1
      IFRAM(1) = NRL
      DO 25 K = 2, NP
25    IFRAM(K) = IFRAM(K-1) + 1
      IF(BX.EQ.1) IXM = 1
      IF(BX.EQ.10**6) IXM = 2
      IF(IUTS.EQ.1) GO TO 20
C
C   U.S. CUSTOMARY UNITS
C
      IF(AY.EQ.1) IYM = 1
      IF(AY.EQ..001) IYM = 2
      GO TO 21
C
C   S I UNITS
C
20    IF(AY.EQ.1) IYM = 1
      IF(AY.EQ..001) IYM = 2
      IF(AY.EQ.1.E-06) IYM = 3
      IF(AY.EQ.1.E-09) IYM = 4
      IF(AY.EQ.1.E-12) IYM = 5
21    CONTINUE
      RL=NRL+0.
      RU=NRU+0.
      IF(IGAG .LE. 0) GO TO 183

```

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```

      JGAG=IGAG-1
      PRINT 181,JGAG,NRL,NRU
181  FORMAT(1H1,* STRESS-STRAIN PCINTS FOR SG-*,12,*   FRAMES *,13,* TH
      IROUGH *,13)
      CALL NOTATE(1.,YLN+.35,.1,3HSG-,0.,3)
      GAG=IGAG-1.
      CALL NUMBER(1.+1.8/7.,YLN+.35,.1,GAG,0.,-1)
      GO TO 189
183  IF( ITEST .NE. 0) GO TO 186
      PRINT 184, IGAGES,NRL,NRU
184  FORMAT(1H1,*STRESS-STRAIN POINTS FOR AVG OF GAGES *,413,*   FRAMES
      I *,13,* THROUGH *,13)
      CALL NOTATE(1.,YLN+.35,.1,6HAVG OF,0.,6)
      N=0
      DO 1845 I=1,4
      IF(IGAGES(I) .EQ. 0) GO TO 1845
      UM=IGAGES(I)
      N=N+1
      CALL NUMBER(1.+3.6/7.+N*1.6/7.,YLN+.35,.1,UM,0.,-1)
1845  CONTINUE
      GO TO 189
186  IF(IGAG .NE. -2)GO TO 188
      PRINT 187, NRL,NRU
187  FORMAT(1H1,* TORQUE TWIST PCINTS, FRAMES *,13,* THROUGH *,13)
      GO TO 189
188  IF(IGAG.NE.0) GO TO 1882
      PRINT 1881, NRL,NRU
1881 FORMAT(1H1,* AVG STRESS-STRAIN POINTS FOR FRAMES *,13,* THROUGH *,
      I13)
      K=1
      DO 10 N=1,18
      IF(NUPLT(N).EQ.0) GO TO 10
      NUPLT2(K)=NUPLT(N)
      K=K+1
10  CONTINUE
      K=K-1
      IF(K.EQ.0) GO TO 15
      PRINT 11
11  FORMAT(1H ,* GAGES OMITTED ARE *)
      PRINT 12, (NUPLT2(N),N=1,K)
12  FORMAT(1H+,22X,18I3)
15  CONTINUE
      CALL NOTATE(1.,YLN+.35,.1,8HAVG PLOT,0.,8)
      GO TO 189
1882 PRINT 1883,NRL,NRU
1883 FORMAT(1H1,* STRESS-STRAIN PCINTS FOR SUM OF GAGES 1 AND 3, FRAMES
      I *,13,* THROUGH *,13)
      CALL NOTATE(1.,YLN+.35,.1,11HSG-1 + SG-3,0.,11)
189  CONTINUE
      IF( IGAG.EQ.-2) GO TO 216
      PRINT 900
900  FORMAT(1H0,1X, 4(28HFRAME      STRESS      STRAIN ))
      IF(IUTS.EQ.1) GO TO 22
      GO TO (200,201) , IYM
200  PRINT 901
901  FORMAT(1H ,1X, 4(28H          PSI          ))
      GO TO 203
201  PRINT 902
902  FORMAT(1H ,1X, 4(28H          KSI          ))
203  GO TO (204,205) , IXM

```


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204 PRINT 903
903 FORMAT(1H+,1X, 4(28H                                IN/IN ))
    GO TO 215
205 PRINT 904
904 FORMAT(1H+,1X, 4(28H                                MICRO ))
    PRINT 905
905 FORMAT(1H ,1X, 4(28H                                IN/IN ))
    GO TO 215
    22 GO TO (206,207,208,209,210), IYM
206 PRINT 906
906 FORMAT(1H ,1X, 4(28H                                PA      ))
    GO TO 212
207 PRINT 907
907 FORMAT(1H ,1X, 4(28H                                KPA     ))
    GO TO 212
208 PRINT 908
908 FORMAT(1H ,1X, 4(28H                                MPA     ))
    GO TO 212
209 PRINT 909
909 FORMAT(1H ,1X, 4(28H                                GPA     ))
    GO TO 212
210 PRINT 910
910 FORMAT(1H ,1X, 4(28H                                TPA     ))
212 GO TO (213,214), IYM
213 PRINT 911
911 FORMAT(1H+,1X, 4(28H                                M/M     ))
    GO TO 215
214 PRINT 912
912 FORMAT(1H+,1X, 4(28H                                MICRO  ))
    PRINT 913
913 FORMAT(1H ,1X, 4(28H                                M/M     ))
    GO TO 215
216 CONTINUE

C
C      TORQUE TWIST DATA
C
    PRINT 915
915 FORMAT(1H0,1X, 4(28HFRAME      TORQUE      TWIST      ))
    IF(IUIS.EQ.1) GO TO 217
    PRINT 916
916 FORMAT(1H ,1X 4(28H            IN-LBS      DEG/IN      ))
    GO TO 215
217 PRINT 917
917 FORMAT(1H ,1X, 4(28H            N-M        RAD/M        ))
215 CONTINUE
    PRINT 191,((IFRAME(N),Y(N),X(N)),N =1,NP)
191 FORMAT(1H ,1X, 4(14,2E12.4))
    CALL NOTATE(1.,YLN+.2,.1,11HFR      -      ,0.,11)
    CALL NUMBER(1.+1.8/7.,YLN+.2,.1,RL,0.,-1)
    CALL NUMBER(1.+4.8/7.,YLN+.2,.1,RU,0.,-1)
    CALL LINPLT(X,Y,NP,1,0,0,1,0)
    RETURN
    END

```

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```

SUBROUTINE SLP(X,Y,XBR,YBR,SP,NU,XMULT,YMULT)
C
C ROUTINE TO DETERMINE LINE OF BEST FIT
C    $Y - YBR = SP * (X - XBR)$ 
C
  DIMENSION X(400),Y(400)
  DO 20 I=1,NU
    X(I)=X(I)/XMULT
  20 Y(I)=Y(I)/YMULT
    XBR = X(1) /NU
    YBR = Y(1) /NU
    DO 10 JK =2, NU
      XBR = XBR + X(JK)/NU
      YBR = YBR + Y(JK)/NU
  10 CONTINUE
C
    AN = X(1)* Y(1)
    DO 11 JK = 2,NU
      AN = AN + X(JK)* Y(JK)
  11 CONTINUE
    AD = X(1)* X(1)
    DO 12 JK =2,NU
      AD = AD + X(JK)* X(JK)
  12 CONTINUE
    SP = (AN - NU* XBR* YBR ) / (AD - NU* XBR * XBR)
    RETURN
  END

SUBROUTINE PROPLIM(X,Y,NRL,NRU,NP,XMULT,YMULT,IUNITS)
  DIMENSION X(400),Y(400),ETAN(400)
  DIMENSION YPS(400),YPTS(400,1),W(400),RESID(400,1),SUM(1),
1  A(3,3),B(3,1),C(400,1),XP(400)
  COMMON UM0VE,IPL0TS,N0PLT(18),XLN,AY,BX,IUTS
  DATA W/400*1.0/
  DO 10 I=1,NP
    X(I)=X(I)/XMULT
  10 Y(I)=Y(I)/YMULT
    DO 150 J =1,NP
      YPTS(J,1) = Y(J)
      XP(J) = X(J)
  150 CONTINUE
    CALLLSQPOL(XP,YPTS,W,RESID,NP,SUM,1,A,B,3,C,400,3)
    DO 151 J = 1,NP
      ETAN(J) = B(2,1) + 2.*B(3,1)*X(J)
    151 KT = 1,NP
      YPS(KT) = B(1,1) + B(2,1)*X(KT) + B(3,1) *X(KT)*X(KT)
    152 PRINT 60
      60 FORMAT(1H1,* STRESS STRAIN TANGENT MODULUS*)
      PRINT 70,((Y(I), X(I),ETAN(I)),I =1,NP)
    70 FORMAT(1H ,3(E12.4,3X))
    CALL CALPLT(XLN+6.,0.,-3)
    CALL BSCALE(ETAN,9.,NP,1,0.,-1,0.)

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CALL BSCALE(Y,9.,NP,1,0.,-1,0.)
IF(IUNITS.EQ.0) CALL AXES(0.,0.,90.,9.,ETAN(NP+1),ETAN(NP+2),1.,0.
1,19HTANGENT MODULUS,PSI,.25,19)
IF(IUNITS.NE.0) CALL AXES(0.,0.,90.,9.,ETAN(NP+1),ETAN(NP+2),1.,0.
1,18HTANGENT MODULUS,PA,.25,18)
IF(IUNITS.EQ.0) CALL AXES(0.,0.,0.,9.,Y(NP+1),Y(NP+2),1.,0.,10HSTR
LESS,PSI,.25,-10)
IF(IUNITS.NE.0) CALL AXES(0.,0.,0.,9.,Y(NP+1),Y(NP+2),1.,0.,9HSTRE
LSS,PA,.25,-9)
CALL DGRID(0.,0.,1.,1.,9,9,0.1)
CALL LINPLT(Y,ETAN,NP,1,0,C,1,0)
RETURN
END

```

```

SUBROUTINE LSQPOL(X,Y,W,RESID,N,SUM,L,A,B,M,C,NMAX,MMAX)
***** DOCUMENT DATE 08-01-68 SUBROUTINE REVISED 08-01-68 *****
C
  DIMENSION X(NMAX),Y(NMAX,L),RESID(NMAX,L),A(MMAX,MMAX),
  2B(MMAX,L),C(NMAX,M),SUM(L),W(NMAX)
C
  10 DO 20 I=1,N
  20 C(I,1)=1.0
  30 DO 50 J=2,M
  40 DO 50 I=1,N
  50 C(I,J)=C(I,J-1)*X(I)
  60 DO 100 I=1,M
  70 DO 100 J=1,M
  80 A(I,J)=0.0
  90 DO 100 K=1,N
  100 A(I,J)=A(I,J)+C(K,I)*C(K,J)*W(K)
  105 DO 150 J=1,L
  110 DO 150 I=1,M
  120 B(I,J)=0.0
  130 DO 150 K=1,N
  150 B(I,J)=B(I,J)+C(K,I)*Y(K,J)*W(K)
  CALL MATINV (A,M,B,L,DETERM,RESID, C,MMAX,1SCALE)
  180 DO 205 J=1,L
  185 SUM(J)=0.0
  KK=M
  192 DO 195 K=1,M
  C(K,1)=B(KK,J)
  195 KK=KK-1
  198 DO 205 I=1,N
  RESID(I,J)=POLYF1(X(I),M,C)-Y(I,J)
  205 SUM(J)=SUM(J)+RESID(I,J)**2*W(I)
  210 RETURN
  END

```

APPENDIX C

DESCRIPTION OF FORTRAN VARIABLES

The following list contains a description of the significant FORTRAN variables appearing in the program. The dimensions for each array are given by using the notation A(m,n). The variables which are input are not presented here since they are described in the section "Input."

<u>FORTTRAN variable</u>	<u>Description</u>
AC2(99)	temporary storage for input data
B(3,1)	stores coefficients of the polynomial fitted to the data points
DTA(415,20)	stores input data for all channels
ETAN(400)	stores tangent moduli at each data point
EX	slope of the line of best fit to a specified section of the curve
FAC	number by which load is divided to get stress (refer to table I)
IPLOTS	number of curves to be plotted for this submission; determined by the computer from information given by the user
KNTRUN	number of plots that have been made for this submission
KOUNT	number of graphs that have been made. This is printed at the end of output.
NP	number of points to be plotted
NPSLP	number of points to be used in finding the slope of the line of best fit
PI	PI = 3.14159
RMAXSS	maximum stress to be plotted
X(400)	stores strain values to be plotted
XMULT	strains, read in units of in./in. are multiplied by XMULT; if the maximum strain is less than 0.1 in./in., XMULT = 10^6 and strains are changed to micro in./in.; otherwise, XMULT = 1. (When data are expressed in SI Units, strain is in m/m and micro m/m.)
XP(400)	temporary storage area used in computing the second-order polynomial which provides the least-squares fit to curve

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<u>FORTTRAN variable</u>	<u>Description</u>
XSC	units per inch on X-axis for stress-strain curves
XSC2	units per inch on X-axis for torque-twist curves
XXLN	distance over which strain values are scaled
Y(400)	stores stress values to be plotted
YMULT	stresses in psi are multiplied by YMULT; if the maximum stress is greater than 1000 psi, YMULT = 0.001 and stresses are changed to ksi; otherwise, YMULT = 1. (When data are expressed in SI Units, stress is in Pa and MPa.)
YPTS(400,1)	temporary storage area used in computing the second-order polynomial which provides the least-squares fit to curve
YSC	units per inch on Y-axis for stress-strain curves
YSC2	units per inch on Y-axis for torque-twist curves

APPENDIX D

LANGLEY LIBRARY SUBROUTINE MATINV

Language: FORTRAN

Purpose: MATINV solves the matrix equation $AX = B$, where A is a square coefficient matrix and B is a matrix of constant vectors. The solution to a set of simultaneous equations, the matrix inverse, and the determinant may be obtained.

Use: CALL MATINV(A,N,B,M,DETERM,IPIVOT,INDEX,NMAX,ISCALE)

A	A two-dimensional array of the coefficients. On return to the calling program, A^{-1} is stored in A
N	The order of A, $1 \leq N \leq NMAX$
B	A two-dimensional array of the constant vectors B. On return to the calling program, X is stored in B
M	The number of column vectors in B. The expression $M = 0$ signals that the subroutine is used solely for inversion; however, in the CALL statement an entry corresponding to B must still be present
DETERM	Gives the value of the determinant by the formula $DET(A) = (10^{100})^{ISCALE}(DETERM)$
IPIVOT	A one-dimensional array of temporary storage used by the routine
INDEX	A two-dimensional array of temporary storage used by the routine
NMAX	The maximum order of A as stated in the DIMENSION-statement of the calling program
ISCALE	A scale factor computed by the subroutine to keep the results of computation within the floating-point word size of the computer

Restrictions: Arrays A, B, IPIVOT, and INDEX have variable dimensions in the subroutine. The maximum size of these arrays must be specified in a DIMENSION statement of the calling program as A(NMAX,NMAX), B(NMAX,M), IPIVOT(NMAX), and INDEX(NMAX,2). The original matrices A and B are destroyed. They must be saved by the user if there is further need for them. The determinant is set to zero for a singular matrix.

Method: Jordan's method is used to reduce a matrix A to the identity matrix I through a succession of elementary transformations l_n, l_{n-1}, \dots, l_1 . $A = I$. If these transformations are simultaneously applied to I and to a matrix B of constant vectors, the results are A^{-1} and X where $AX = B$. Each transformation is selected so that the largest element is used in the pivotal position. (See ref. (a).)

Accuracy: Total pivotal strategy is used to minimize the rounding errors; however, the accuracy of the final results depends upon how well-conditioned the original matrix is.

Reference: (a) Fox, L.: An Introduction to Numerical Linear Algebra. Oxford Univ. Press, 1965.

Storage: 542g locations.

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A listing of subroutine MATINV is as follows:

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SUBROUTINE MATINV(A,N,B,M,DETERM,IPIVOT,INDEX,NMAX,ISCALE)
***** DOCUMENT DATE 08-01-68   SUBROUTINE REVISED 08-01-68 *****
C
C   MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQUATIONS
C
C   DIMENSION IPIVOT(N),A(NMAX,N),B(NMAX,M),INDEX(NMAX,2)
C   EQUIVALENCE (IROW,JROW), (ICOLUJ,JCOLUJ), (AMAX, T, SWAP)
C
C   INITIALIZATION
C
      5 ISCALE=0
      6 R1=10.0**100
      7 R2=1.0/R1
      10 DETERM=1.0
      15 DO 20 J=1,N
      20 IPIVOT(J)=0
      30 DO 550 I=1,N
C
C   SEARCH FOR PIVOT ELEMENT
C
      40 AMAX=0.0
      45 DO 105 J=1,N
      50 IF (IPIVOT(J)-1) 60, 105, 50
      60 DO 100 K=1,N
      70 IF (IPIVOT(K)-1) 80, 100, 740
      80 IF (ABS(AMAX)-ABS(A(J,K))) 85, 100, 100
      85 IROW=J
      90 ICOLUJ=K
      95 AMAX=A(J,K)
     100 CONTINUE
     105 CONTINUE
      IF (AMAX) 110, 106, 110
     106 DETERM=0.0
      ISCALE=0
      GO TO 740
     110 IPIVOT(ICOLUJ)=IPIVOT(ICOLUJ)+1
C
C   INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
     130 IF (IROW-ICOLUJ) 140, 260, 140
     140 DETERM=-DETERM
     150 DO 200 L=1,M
     150 SWAP=A(IROW,L)
     170 A(IROW,L)=A(ICOLUJ,L)
     200 A(ICOLUJ,L)=SWAP
     235 IF(M) 260, 260, 210
     210 DO 250 L=1, M
     220 SWAP=B(IROW,L)
     230 B(IROW,L)=B(ICOLUJ,L)
     250 B(ICOLUJ,L)=SWAP
     260 INDEX(I,1)=IROW
     270 INDEX(I,2)=ICOLUJ
     310 PIVOT=A(ICOLUJ,ICOLUJ)
      IF (PIVOT) 1000, 106, 1000
C
C   SCALE THE DETERMINANT
C
     1000 PIVOTI=PIVOT
     1005 IF (ABS(PIVOTI)-R1) 1030, 1010, 1010
     1010 DETERM=DETERM/PIVOTI
      ISCALE=ISCALE+1
      IF (ABS(DETERM)-R1) 1060, 1020, 1020

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1020 DETERM=DETERM/R1
      ISCALE=ISCALE+1
      GO TO 1060
1030 IF (ABS(DETERM)-R2) 1040,1040,1060
1040 DETERM=DETERM*R1
      ISCALE=ISCALE-1
      IF (ABS(DETERM)-R2) 1050,1050,1060
1050 DETERM=DETERM*R1
      ISCALE=ISCALE-1
1060 IF (ABS(PIVOTI)-R1) 1090,1070,1070
1070 PIVOTI=PIVOTI/R1
      ISCALE=ISCALE+1
      IF (ABS(PIVOTI)-R1) 320,1080,1080
1080 PIVOTI=PIVOTI/R1
      ISCALE=ISCALE+1
      GO TO 320
1090 IF (ABS(PIVOTI)-R2) 2000,2000,320
2000 PIVOTI=PIVOTI*R1
      ISCALE=ISCALE-1
      IF (ABS(PIVOTI)-R2) 2010,2010,320
2010 PIVOTI=PIVOTI*R1
      ISCALE=ISCALE-1
320 DETERM=DETERM*PIVOTI
C
C   DIVIDE PIVOT ROW BY PIVOT ELEMENT
C
330 A(ICOLU,ICOLU)=1.0
340 DO 350 L=1,N
350 A(ICOLU,L)=A(ICOLU,L)/PIVOT
355 IF (M) 360, 380, 360
360 DO 370 L=1,M
370 B(ICOLU,L)=B(ICOLU,L)/PIVOT
C
C   REDUCE NON-PIVOT ROWS
C
380 DO 550 L1=1,N
390 IF (L1-ICOLU) 400, 550, 400
400 T=A(L1,ICOLU)
420 A(L1,ICOLU)=0.0
430 DO 450 L=1,N
450 A(L1,L)=A(L1,L)-A(ICOLU,L)*T
455 IF (M) 550, 550, 460
460 DO 500 L=1,M
500 B(L1,L)=B(L1,L)-B(ICOLU,L)*T
550 CONTINUE
C
C   INTERCHANGE COLUMNS
C
600 DO 710 I=1,N
610 L=N+1-I
620 IF (INDEX(L,1)-INDEX(L,2)) 630, 710, 630
630 JROW=INDEX(L,1)
640 JCOLUM=INDEX(L,2)
650 DO 705 K=1,N
660 SWAP=A(K,JROW)
670 A(K,JROW)=A(K,JCOLUM)
700 A(K,JCOLUM)=SWAP
705 CONTINUE
710 CONTINUE
740 RETURN
      END

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APPENDIX E

STRAIN AND DISPLACEMENT TRANSDUCER LOCATIONS
ON TORSION SPECIMEN

Most torsion tests on tubular specimens are conducted with one or more strain rosettes and four LVDT's or similar instruments for measuring rotation. In order to keep user instructions at a minimum, a pattern for identifying the strain gages and rosettes was selected. (See fig. 10.) Starting with the first strain rosette and continuing clockwise around the circumference of the cylinder, the strain transducers are numbered in monotonically increasing order. The first and last transducers in each rosette are oriented at -45° and $+45^{\circ}$, respectively, to the longitudinal axis of the specimen. As shown in figure 10, LVDT's number 1 and 2 measure displacements of radial arms at a station near the rotated end of the tube (δ_1 and δ_2) whereas LVDT's 3 and 4 measure displacements δ_3 and δ_4 , respectively, near the fixed end of the tube. Utilization of a different pattern for identifying transducers will generally require changes in the program in order to generate accurate and usable plots.

REFERENCE

1. Anon.: Metric Practic Guide. E 380-72, Amer. Soc. Testing & Mater., June 1972.

TABLE I. - PROGRAM CAPABILITY

Case	Specimen	Test	Plot on Y-axis	Plot on X-axis	Compute slope	Compute tangent modulus
1	Flat	Compression or tension	$\sigma = \frac{P}{wt}$	$\epsilon_1, \epsilon_2, \dots, \epsilon_{18}$	No	No
2	Flat	Compression or tension	$\sigma = \frac{P}{wt}$	$\epsilon_1, \epsilon_2, \dots, \epsilon_{18}$ and average of strains from up to four gages	Yes, for averaged curve	Yes, for averaged curve
3	Flat	Compression or tension	$\sigma = \frac{P}{wt}$	Average of strains from up to four gages	Yes	Yes
4	Tube	Compression or tension	$\sigma = \frac{P}{\pi(O.D. - t)t}$	$\epsilon_1, \epsilon_2, \dots, \epsilon_{18}$	No	No
5	Tube	Compression or tension	$\sigma = \frac{P}{\pi(O.D. - t)t}$	$\epsilon_1, \epsilon_2, \dots, \epsilon_{18}$ and average of strains from up to four gages	Yes, for averaged curve	Yes, for averaged curve
6	Tube	Compression or tension	$\sigma = \frac{P}{\pi(O.D. - t)t}$	Average of strains from up to four gages	Yes	Yes
7	Tube	Torsion	$\tau = \frac{2T}{\pi(O.D. - t)^2t}$	$\epsilon_1, \epsilon_2, \dots, \epsilon_{18}$	No	No
8	Tube	Torsion	$\tau = \frac{2T}{\pi(O.D. - t)^2t}$	$\epsilon_1, \epsilon_2, \dots, \epsilon_{18}$ and sum of absolute values from $\pm 45^\circ$ gages in one rosette	Yes, for sum of absolute values from $\pm 45^\circ$ gages	Yes, for sum of absolute values from $\pm 45^\circ$ gages
9	Tube	Torsion	$\tau = \frac{2T}{\pi(O.D. - t)^2t}$	Average of sum of absolute values from all $\pm 45^\circ$ gage	Yes	Yes
10	Tube	Torsion	$\tau = \frac{2T}{\pi(O.D. - t)^2t}$ and T	Average of sum of absolute values from all $\pm 45^\circ$ gages and $\theta = \frac{180(\delta_1 + \delta_2 - \delta_3 - \delta_4)}{2\pi R\ell}$	Yes, for averaged strain curve and for torque-twist curve	Yes, for averaged stress-strain curve

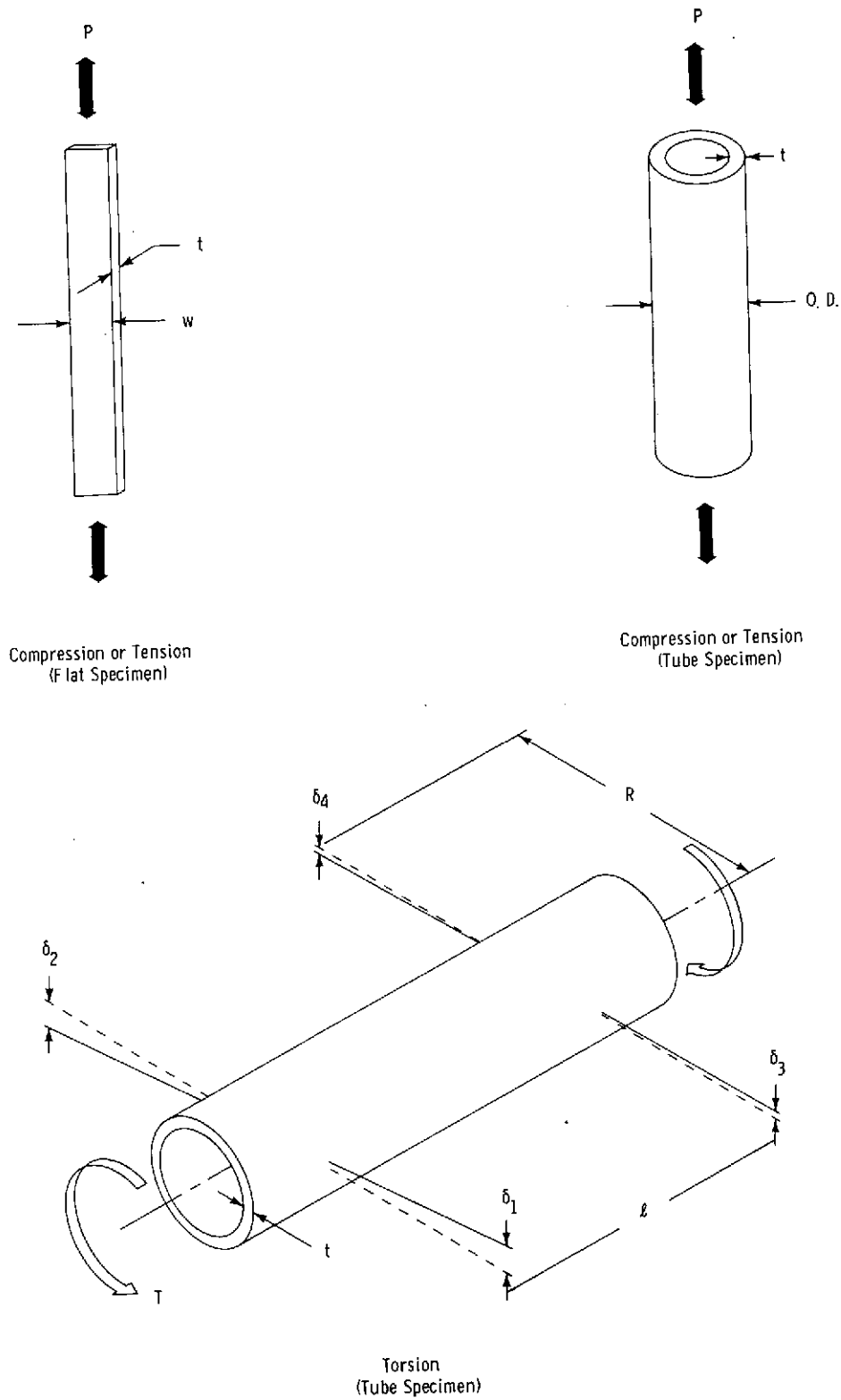


Figure 1.- Specimen geometry for compression, tension, and torsion tests.

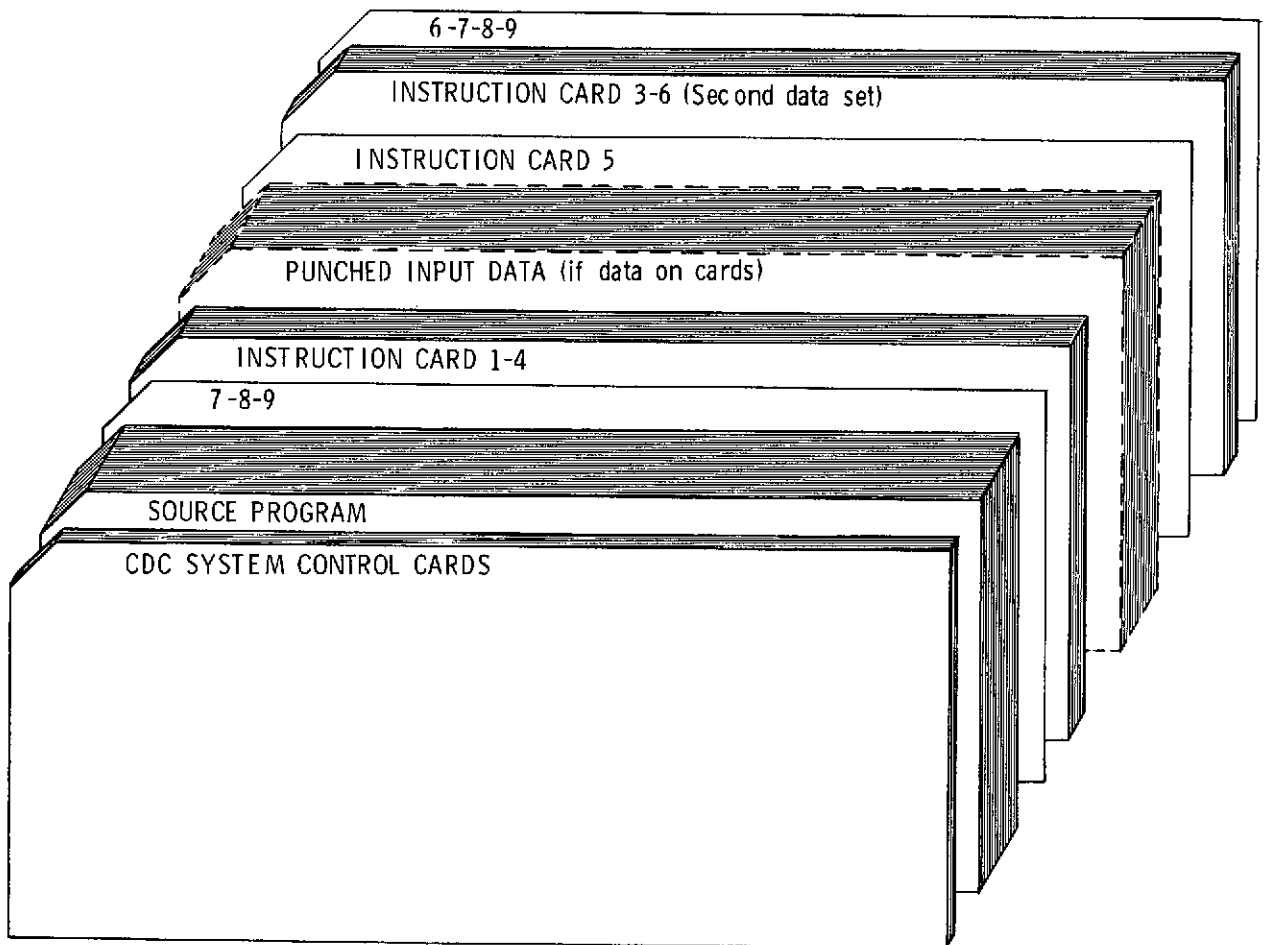


Figure 2.- Program BECKPLT deck setup.

PROBLEM 1 COMPRESSION TEST

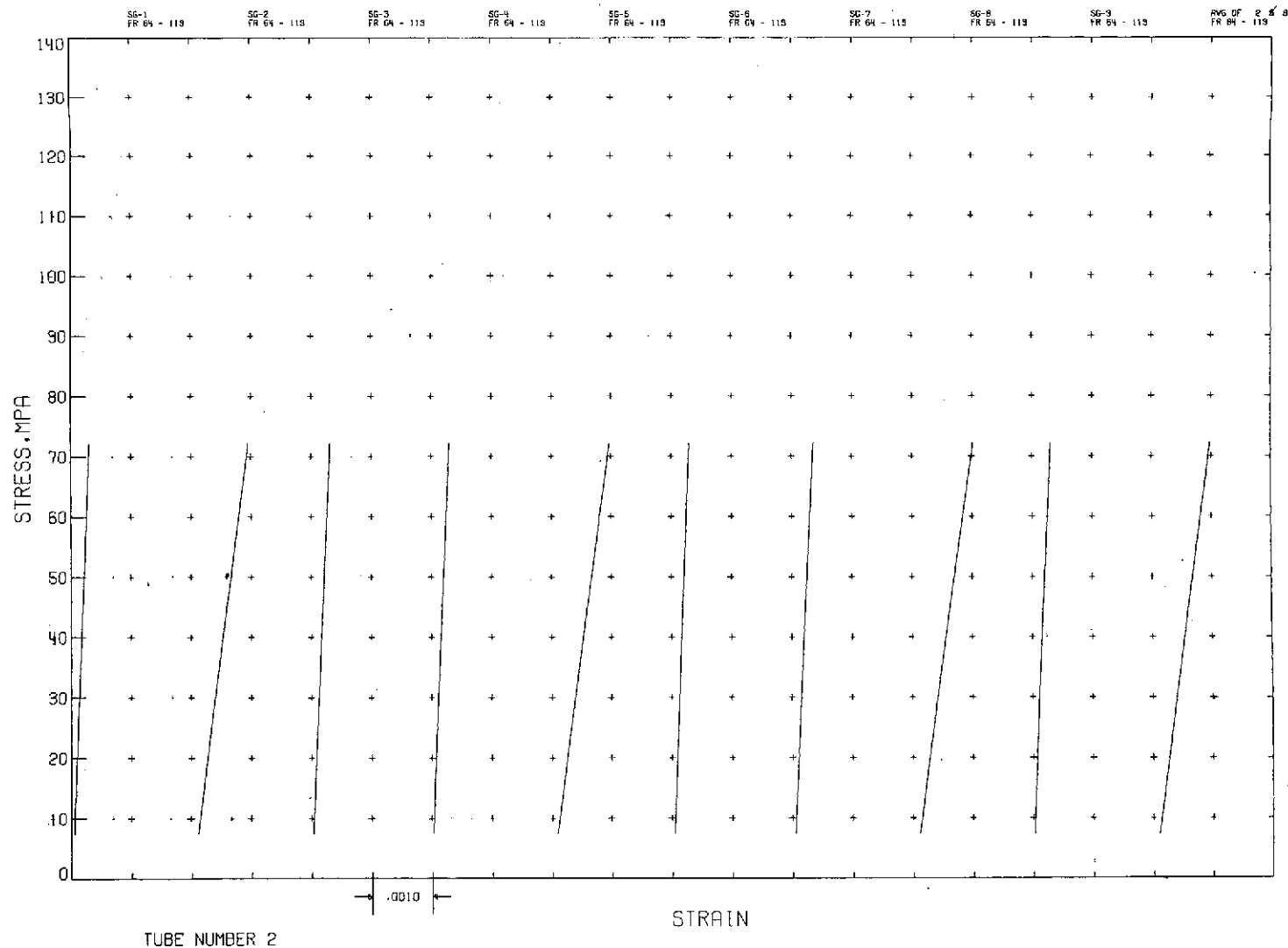


Figure 3.- Stress-strain plots developed from compression test on graphite-epoxy tube.

PROBLEM 2 COMPRESSION TEST

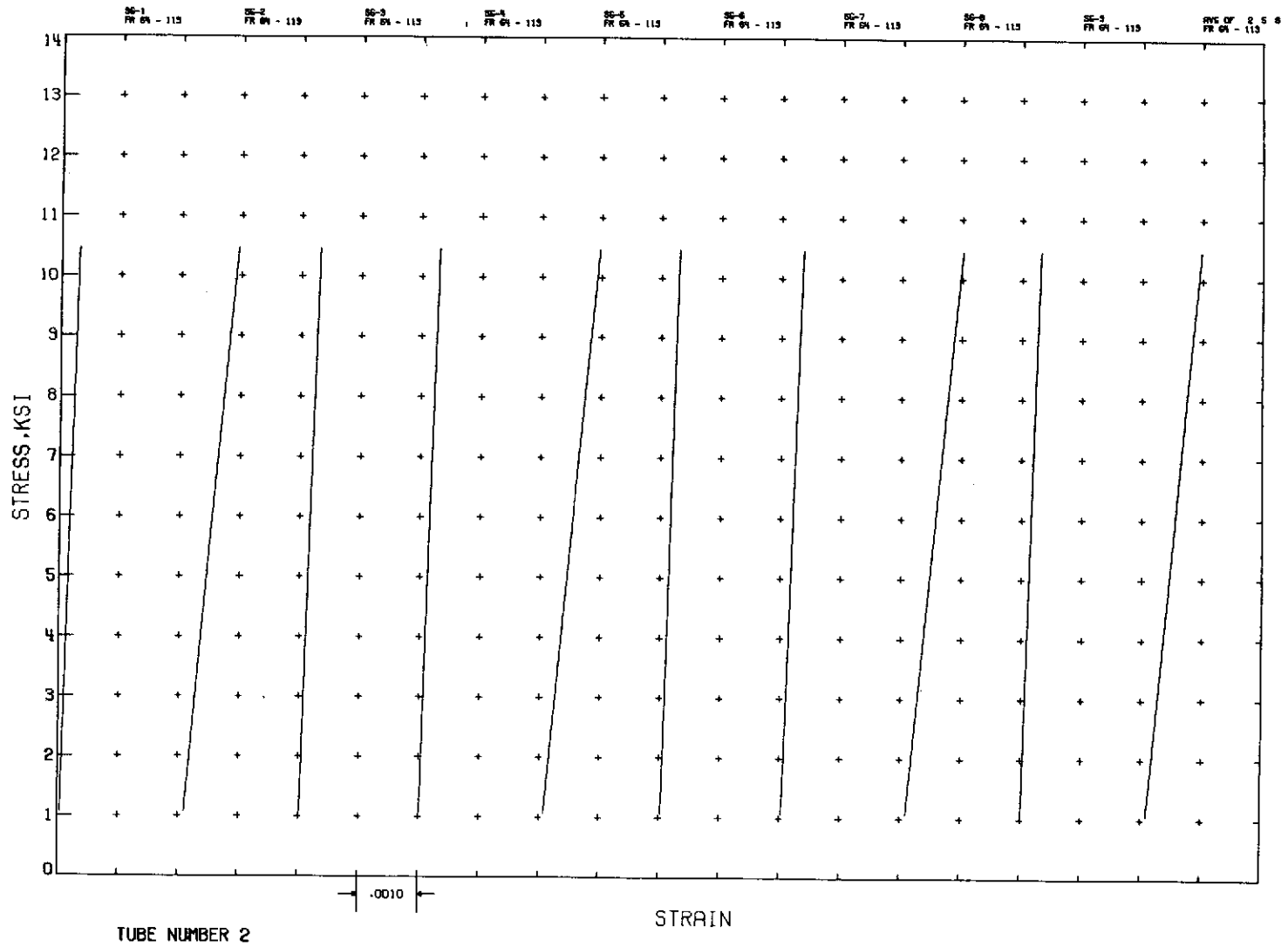


Figure 4.- Stress-strain plots developed from compression test on graphite-epoxy tube.

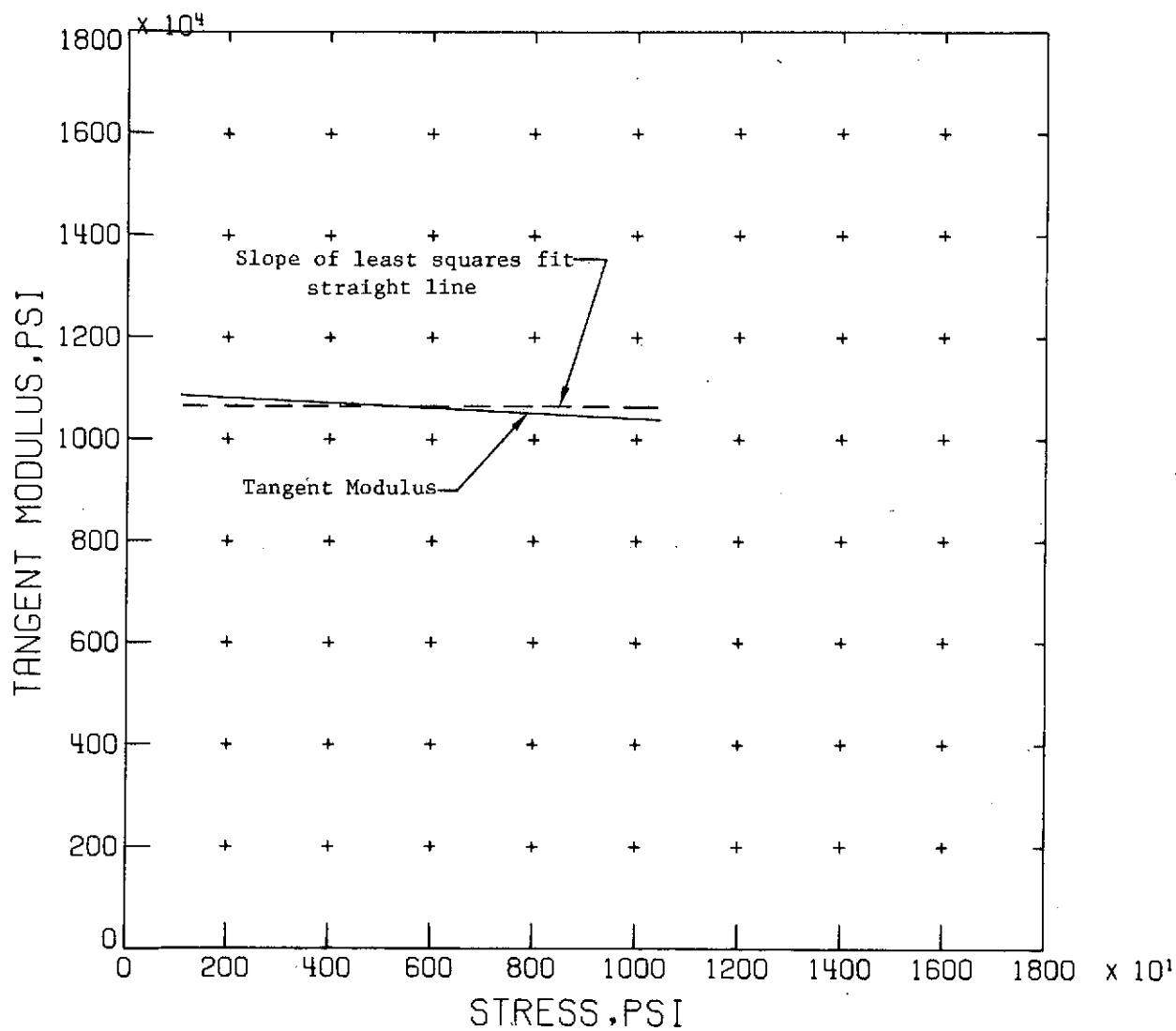


Figure 5.- Tangent-modulus—compressive-stress curve developed from compression test on graphite-epoxy tube.

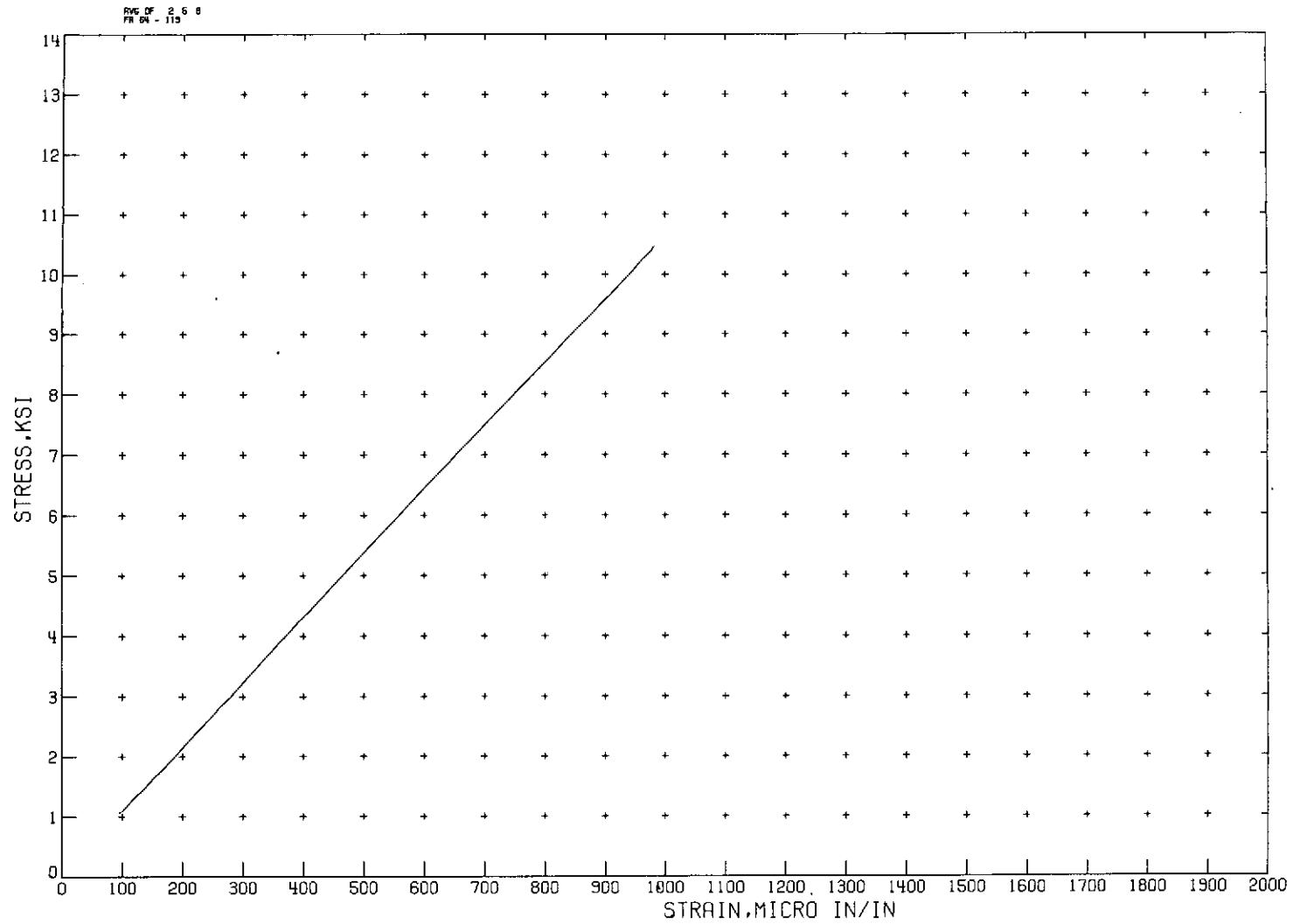


Figure 6.- Average stress-strain curve developed from compression test on graphite-epoxy tube.

PROBLEM 3 TORSION TEST

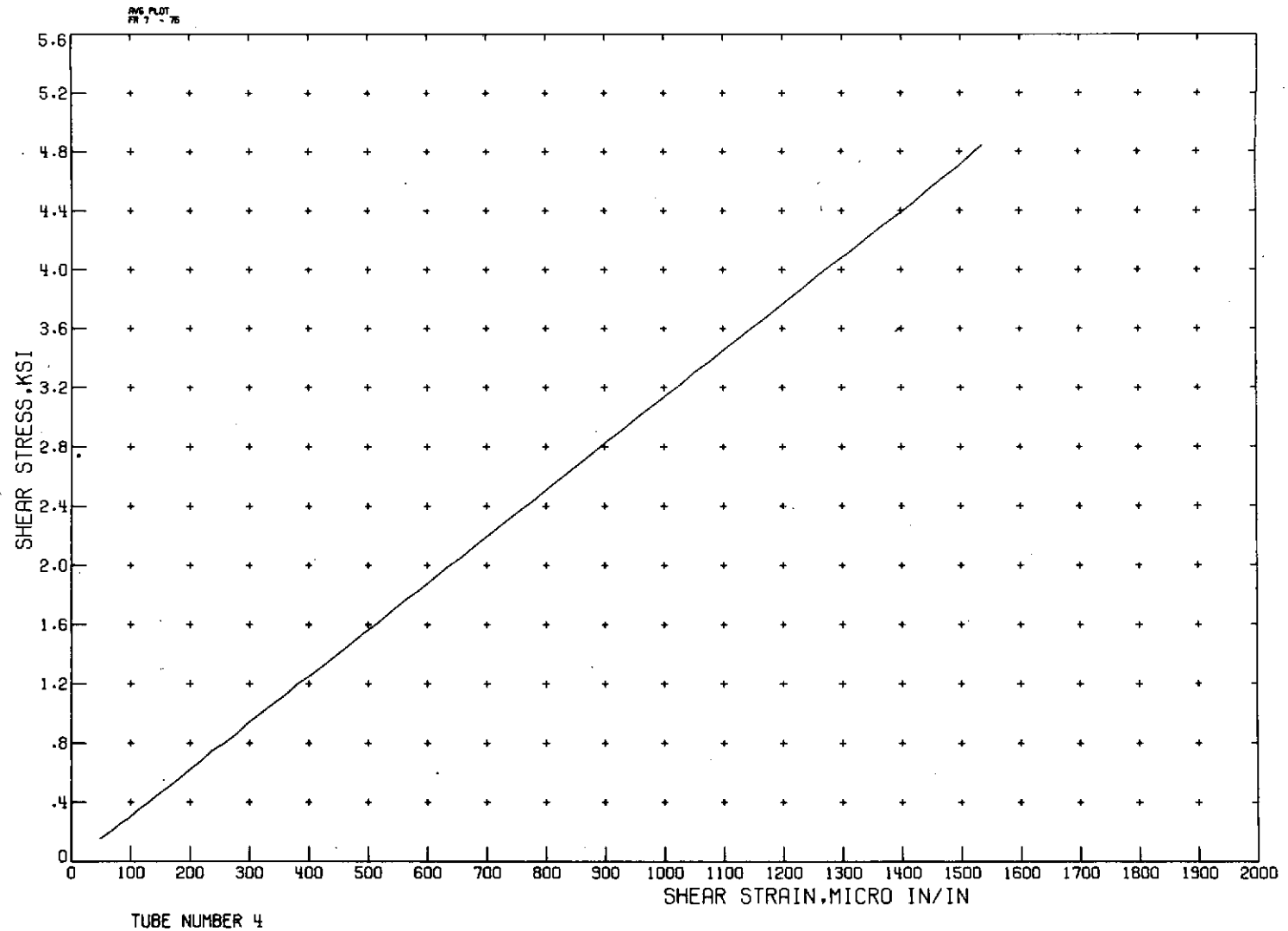


Figure 7.- Shear-stress—shear-strain curve developed from torsion test on a graphite-epoxy tube.

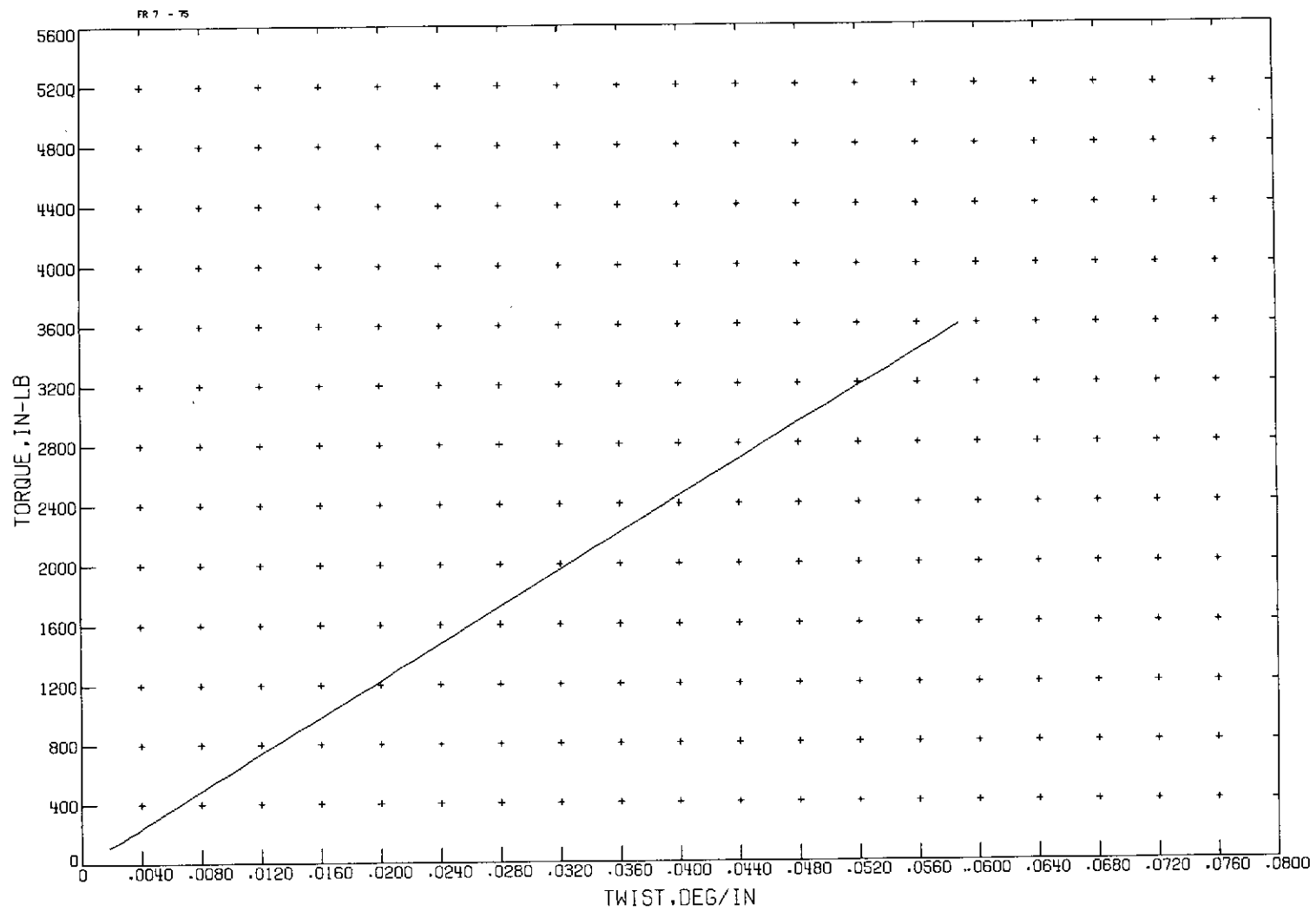


Figure 8.- Torque-twist curve for graphite-epoxy tube.

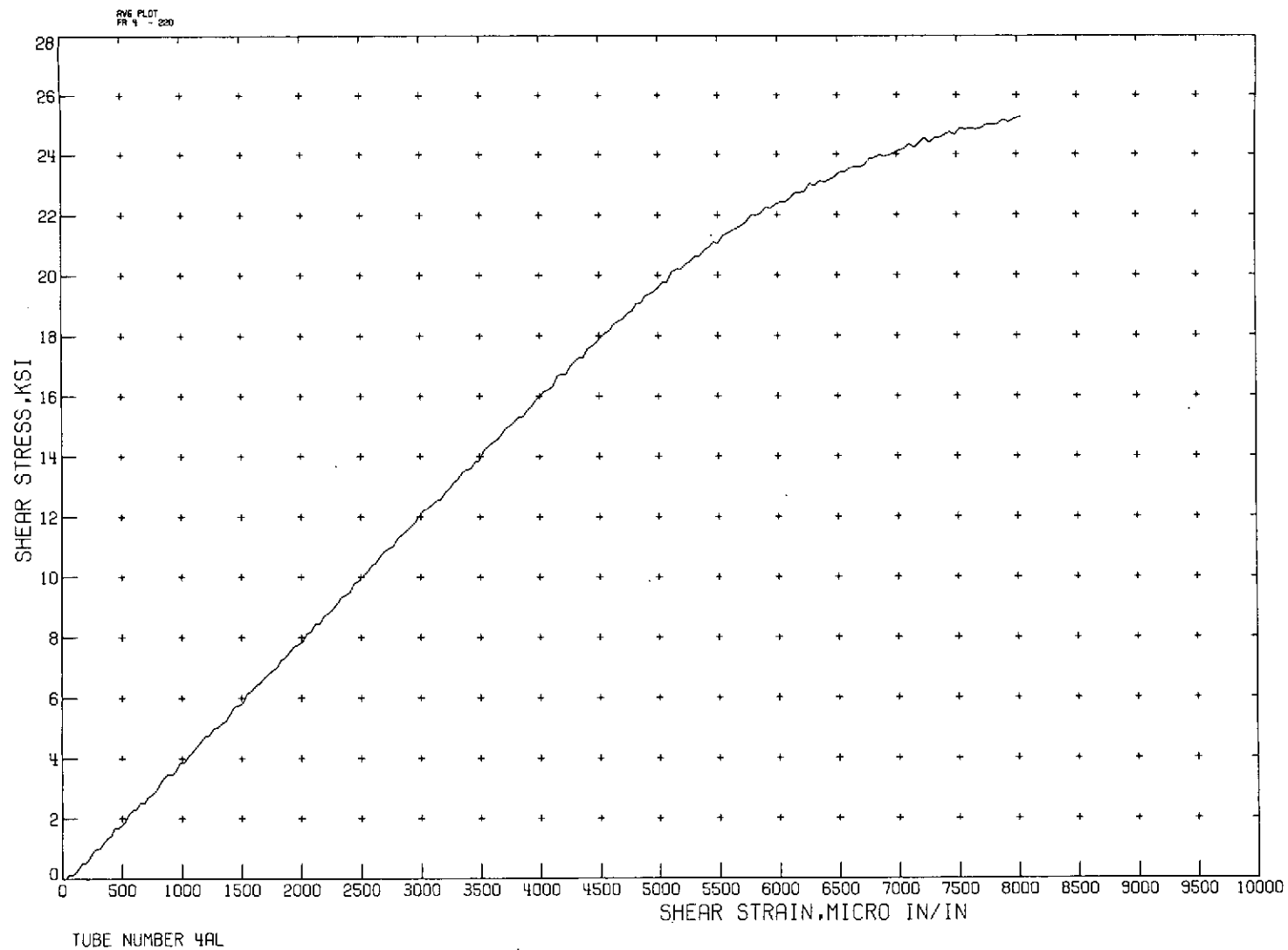
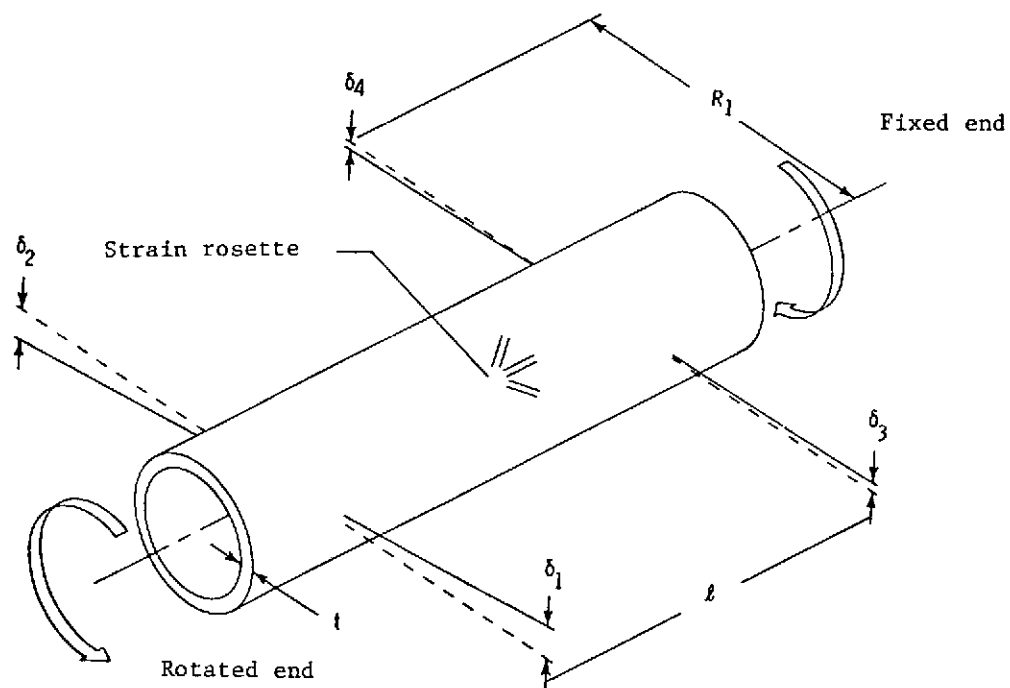
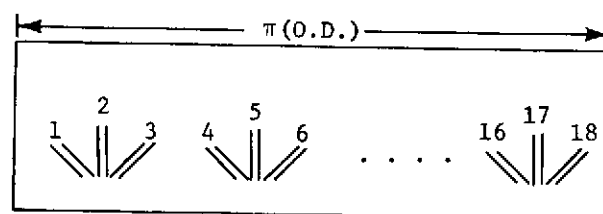


Figure 9.- Shear-stress—shear-strain curve developed from torsion test on aluminum tube.



Overview of torsion specimen



Circumferential strain gaged section of specimen

Figure 10.- Overview of torsion specimen and identification of strain-gage and LVDT numbering sequence.